Agricultural information services in Khulna, Bangladesh

Identification of success factors in a review of agricultural information services in peri-urban Khulna, Bangladesh

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Frontpage image: Workshop on the development of information services for farmers in peri-urban Khulna, Bangladesh on May 6th, 2018. Retrieved from deltacapproject.net, on July 31, 2018.

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Abstract

The peri-urban areas around Khulna, Bangladesh are facing an erratic water supply, urbanisation process, and a variety of natural calamities, each affecting local food and livelihood security. Several information services have been developed by public and private parties that aim to assist farmers in their hydroclimatic risk and agricultural management. Farmers can potentially benefit if they have access to such services and attune their agricultural decision-making appropriately to available information. Yet, it is not comprehensively researched which services are available, nor to what extent their existence has affected farmers' decision-making so far. This thesis first researches which services are available in peri-urban Khulna. Next it researches which underlying factors relating to (1) the targeted user and (2) design parameters of the service can be attributed to a decision-making factor using a multi-value Qualitative Comparative Analysis (mvQCA). Results indicate, combining television programs or personal field-level approaches with user feedback elements gives a service the highest chance of success. While mobile phone communication opportunities are on the rise, farmers frequently lack access to (digital) technology. Additionally, they have limited understanding of weather forecasts, and often tend to rely on indigenous climatic knowledge. While developers tend to overestimate the impacts of their service by assuming farmers incorporate available information into their decision-making, they have the potential to improve their service by implementing a user feedback mechanism. This MSc thesis is part of the WaterApps project, which aims to co-create water information services in Accra, Ghana and Khulna, Bangladesh.

Keywords: agriculture, Bangladesh, information services, Qualitative Comparative Analysis

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List of acronyms

ABP	Ananda Bazar Patrika
AIS	Agriculture Information Service
AIR	All India Radio
ATN	Asian Television Network
AWS	Automatic Weather Station
BB	Bangladesh Betar
BCAS	Bangladesh Centre for Advance Studies
BIID	Bangladesh Institute for ICT Development
BMD	Bangladesh Meteorological Department
BSS	Bangladesh Sangbad Sangstha
BTRC	Bangladesh Telecom Regulatory Commission
BTV	Bangladesh Television
cs	Crisp set
CSRD	Climate Services for Resilient Development
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DD	Doordarshan
FAO	Food and Agriculture Organisation
FFS	Farmer Field School
FFWC	Flood Forecasting and Warning Centre
FM	Frequency Modulation
fs	Fuzzy set
GTV	Gazi Television
GDP	Gross Domestic Product
IMD	India Meteorological Department
IT	Information Technology
LGED	Local Government Engineering Department
MoA	Ministry of Agriculture
MoES	Ministry of Earth Sciences
MoFDM	Ministry of Food and Disaster Management
MoP	Ministry of Planning
mv	Multi-value
NOAA	National Oceanic and Atmospheric Administration
QCA	Qualitative Comparative Analysis
SWC	Storm Warning Centre
ToT	Training of Trainers

1 Introduction

1.1 Agricultural information services

Following global advancements in the technological sector, Information Technology (IT) tools related to the agricultural sector are increasingly available (Aker, 2011). Such tools provide water, climatic or crop-related data to its end-users through (digital) dissemination, and will in this thesis collectively with information flows from alternative sources (e.g. extension work, print media) be called agricultural information services. Farmers can use such services as a source of information about among others pests, seeds, fertilizers and, crop diseases (Aker, 2011). They can also be used to stimulate farmers into adopting new practices (Ani *et al.*, 1997). Enabling smallholder farmers to making better-informed decisions regarding production activities or yield marketing are also included in the expected benefits (Lwoga, 2010). Moreover, seizing opportunities from available technology may aid farmers in reduction of costs and labour, or assist in management of the hydro-climatic risks they face by means of guidance through decisive stages (Rose *et al.*, 2016; Dicks *et al.*, 2014). Such services can especially be relevant in developing countries, where agriculture can act as an important engine of economic growth (Aker, 2011).

Although aforementioned socioeconomic advantages appear promising, there is evidence indicating decision-support potential is not always fulfilled. Apart from consequences of mere technical limitations[1], decision-support has repeatedly been found not to be successful due to low acceptance by its users (Kuhlmann & Brodersen, 2001; Carayannis & Sagi, 2000; Cox, 1996). Furthermore, widespread use and benefits for smallholder farmers have been reported to be limited by constraints regarding among others their understanding or response capacity (Hansen *et al.*, 2011). A possible explanation for this phenomenon can be found when examining farmers' customs: Traditional smallholders tend to rely on indigenous or religious knowledge, often being not as (digitally) literate as researchers (Cox, 1996). Also, present forecasting systems are not understandable nor accessible for all users of vulnerable communities, and are therefore not triggering response or preparedness for action (Chowdhury, 2005). Additionally, previous experiences with inadequate information may lead to ignored disaster warnings (Howell, 2003). This thesis thus underpins the importance of understanding the interaction between user and service in the light of analysing implementation problems associated with these services.

In this MSc thesis, part of the overarching WaterApps project, an attempt is made to examine existing agricultural information services in Khulna, Bangladesh in order to gain a better understanding of aforementioned implementation limitations. WaterApps is being coordinated by Wageningen University and a number of representatives from the public and private sectors in the Netherlands, Ghana and Bangladesh. The overall project goal is to co-create localised water information services in the coastal peri-urban areas of Accra, Ghana and Khulna, Bangladesh using virtual communities and knowledge sharing platforms (NWO, 2018). In this project, local farmers co-produce water information services, leading to contributions to among others livelihood improvement and enhanced sustainable food production (NWO, 2018).

[1] Technical limitations are not more elaborately addressed in this thesis. For literature on problems related to the timeliness of forecasted information, please consult Islam *et al.* (2013). Problems with insufficiently localised or inaccurate data have been described by Paul & Routray (2013).

1.2 Bangladesh: an emerging nation

This subsection will elaborate on the current state of development in Bangladesh, a country in South-Asia bordering India and Myanmar. This section will describe various underlying developmental processes in Bangladesh including demographic, climatic and agricultural aspects.

Demography
The population density in Bangladesh is high, with around 1250 inhabitants per square kilometre in 2016 (World Bank, 2018a). Not accounting for mini-states with a surface area of less than 700 km2, Bangladesh is worldwide the most densely-populated country. Sixty-six percent of the inhabitants live in rural areas, while the remaining citizens live in cities like the capital Dhaka (PRB, 2016). Additionally, the country is currently involved in a high population growth of around two percent annually (Rasul & Thapa, 2003). Whereas in 2016 Bangladesh had around 163 million inhabitants, its population doubled during the past 30 years (World Bank, 2018a).

In 1991, around 58 percent of the inhabitants of Bangladesh were estimated to live below the poverty line (World Bank, 2002). Although this alarmingly high number decreased impressively to 31.5 percent in 2010 (World Bank, 2011; Serajuddin *et al.*, 2010), Bangladesh remains a lower middle income country (World Bank, 2018b), with poverty mainly manifested in its rural areas. In addition, an ongoing urbanisation process in Bangladesh is luring people away from the these areas in search for better livelihood opportunities. Urbanisation is known to influence employment opportunities, livelihood dynamics, and marketing fortuities, caused by a combination of fast land use change, population growth and increased connectivity between urban and rural areas (Patil, 1999; Hunshal, 1997; Allen, 2000; Hugo, 2007). The rural areas, inhabited by millions of smallholder and marginal farmers, traditionally provided the vast majority of the Bengals with employment opportunities.

Climate and environment
Located on both sides of the Tropic of Cancer, Bangladesh has a tropical climate, with a pleasant winter season from October to March and a humid and hot summer from March to June. Average monthly temperatures vary from 18 degrees in January to 28 degrees in August, while most precipitation falls during the warm monsoon season, with intense peaks in June, July and August (World Bank, 2016). Bangladesh is a mostly flat and fertile country, being in a lower riparian state to the three large rivers Ganges, Brahmaputra and Meghna and numerous smaller ones.

Bangladesh is prone to a range of natural calamities, of which several studies show flooding is the most significant (MoFDM, 2006; Nasreen, 1998; Kumbetoglu & User, 2010). Although riverine flooding is caused by natural processes like snowmelt in the Himalayas and heavy precipitation during the monsoon season, human factors like deforestation and anthropogenic climate change may additionally intensify the severity of floods (Ives, 1989). This causes material damage to infrastructure, health risks, and financial losses to thousands of inhabitants. There is also evidence pointing out that inundated land increases its fertility rate due to sedimentary deposition of nutrients (Milliman & Meade, 1983; Karim *et al.*, 1991). Other natural hazards include droughts and sea-level rise (MoFDP, 2006; Huq, 2001), which occur increasingly frequent and/or severe due to climate change (Delaporte & Maurel, 2016; Huq *et al.*, 2015; Field *et al.*, 2012; IPCC, 2014). Coastal areas located near the Indian ocean additionally experience the hazards of salinity intrusion and storm surges, encouraged by climate change (Huq *et al.*, 2015). Cyclones hitting the coastal area of Bangladesh, frequently occurring right before and after the monsoon

season, are among the deadliest in the world (Quadir & Iqbal, 2008).

Agriculture and water
Historically, Bangladesh has been economically heavily dependent on its agricultural sector, accounting for 78 percent of the national Gross Domestic Product (GDP) in 1971 and employing around two-thirds of the rural citizens across the country (Alam *et al.*, 2009; MoP, 1997). Fast-forwarding to more recent times, the contribution of agriculture to the GDP is only slightly over twenty percent in 2008 and utterly fifteen percent in 2016, implying drastic changes as to the importance of the sector over the past four decades (Khosruzzaman *et al.*, 2010; Alam *et al.*, 2009; BBS, 2017). Nonetheless, according to the FAO (Food and Agriculture Organisation of the UN), national food production and availability are currently insufficient to nourish all citizens (FAO, 2017). Underutilization of agricultural technologies such as cultivars and fertilizers could be an explanation (Aker, 2011).

Salinity intrusion in the coastal areas increasingly deteriorates the quality of surface water (Rahman *et al.*, 2012). While groundwater in Bangladesh is the main source of irrigation water (Shirazi *et al.*, 2011), the majority of the aquifers in the coastal area are known to be intruded with seawater (Rahman *et al.*, 2011; 2012). As a result, sufficient water supply of sufficient quality is increasingly becoming unpredictable, especially in the coastal regions.

Commonly grown crops in Bangladesh are rice, wheat, and maize (MoA, 2018). Rice is grown twice or thrice per year and is the most cultivated crop in terms of yield. The coastal region is known to be ecologically rich and economically productive due to its combined tidal estuaries and mangrove forests (Huq *et al.*, 2015). While groundwater in Bangladesh is the main source of irrigation water (Shirazi *et al.*, 2011), the majority of the aquifers in the coastal area are known to be intruded with seawater (Rahman *et al.*, 2011; 2012). As the South Asian monsoon season has intensified its precipitation and dry periods occur more often compared to thirty years ago, water resources are being impacted adversely (Singh *et al.*, 2014). Moreover, the monsoon only provides rain water half of the year. A higher variability in climatic conditions and rainfall results in increasingly difficult agricultural decision-making (Reid *et al.* 2009). As a result, the farming communities of Bangladesh are highly vulnerable to climate change (Huq *et al.*, 2015).

1.3 The study area

This study has been conducted around the city of Khulna, in the southwest of Bangladesh. This city is the administrative seat of both the Khulna division (bibhag) and the Khulna district (zila) within the division. Khulna city once developed as a settlement along the Rupsha river and currently also serves as gateway to the world's largest mangrove forest, the Sundarbans. The area around Khulna city is inhabited by smallholder farming communities, the soil is known for its fertility and there is an ongoing urbanisation process. Additionally, this area experiences a high population density and growth and a wide range of occurring calamities, both natural ones and those enhanced by anthropogenic climate change. Khulna is located in the coastal area, where concerns over salt-intruded aquifers limit groundwater irrigation (Mondal *et al.*, 2008). Furthermore, the coastal regions of Bangladesh are vulnerable and exposed to effects of storm surges and coastal flooding (Huq *et al.*, 2015).

Khulna district is divided into 9 upazilas, which have a function similar to sub-districts. See Figure 1 for a schematic representation of the area. To gain understanding of the modus

operandi of information services in peri-urban areas, two sites close to the city of Khulna have been chosen. Peri-urban areas are located within the periphery of the urbanisation process of the adjacent city, in this case Khulna (Khulna city has been indicated with a blue circle in Figure 1). Hence, this study is primarily targeted at the nearby Batiaghata upazila (bottom right subfigure in Figure 1), but also a few activities have taken place in the neighbouring Dumuria upazila (bottom left subfigure in Figure 1). Both upazilas are inhabited by smallholder farming communities, producing rice, vegetables, fruit, and fish for household level and occasionally for local markets. Batiaghata is located directly south of Khulna city, showing development characteristics connected to the expansion of Khulna city. The villages visited in Dumuria, located west of Khulna city, are agroecologically and climatically situated in similar conditions to the ones in Batiaghata, but are set in a more rural environment.

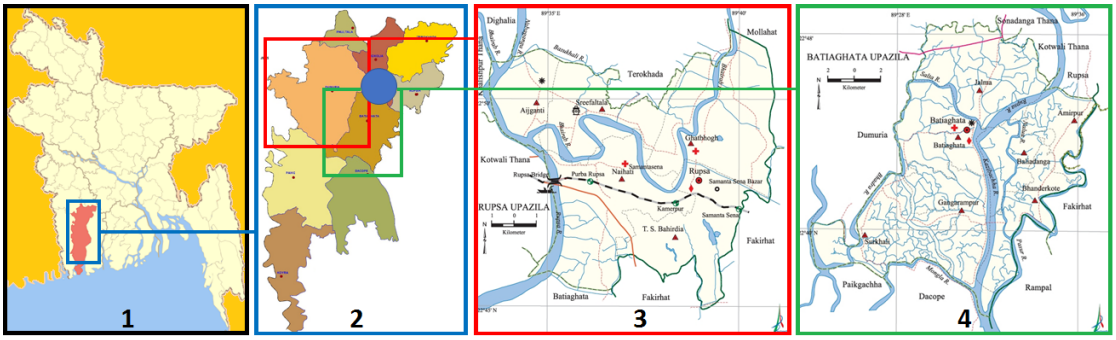


Figure 1: From left to right: (1) Bangladesh and surroundings, (2) Khulna district, (3) Dumuria upazila and (4) Batiaghata upazila. Adapted from en.wikipedia.org/wiki/Khulna_District, en.banglapedia.org, and the LGED, accessed July 22nd, 2018.

1.4 Problem statement

Although agricultural information services are designed intending to effectuate socioeconomic advantages for their users, there is evidence in literature indicating their potential is not always fulfilled. It is likely that information service implementation problems identified from literature are currently occurring in peri-urban Khulna, as it is a developing area in a highly complex social and environmental context. Still, it is not known to what extent existing services succeed in effectuating societal benefits. Firstly this is the case because no inclusive summary or review of existing agricultural information services has been made as of yet. Secondly, it is not understood to what extent these services have already contributed to improved decision-making or otherwise affected on-farm cultivation processes, or why they possibly fail to do so. The problem statement of this study can be formulated as follows:

> *It is insufficiently known why some agricultural information services in peri-urban Khulna change farmer decision-making, while others do not.*

1.5 Objectives and research questions

This thesis has three objectives. The first objective is to make an overview of previously introduced information services in peri-urban Khulna. Secondly, this thesis attempts to unveil why certain services fulfil their potential while others may not. The third objective is to identify opportunities and challenges for a future generation of agricultural information services. To achieve

compliance with the objectives pursued in this study, the following main research question (RQ) will be answered.

> *What makes an agricultural information service change farmer decision-making in peri-urban Khulna, Bangladesh?*

To break down this question, a number of sub questions (SQs) have been formulated. The structure of the methodology as presented in chapter three will explain which activities conducted for this thesis are linked to which sub questions.

SQ1: Which factors influencing information service use can be retrieved from literature?
SQ2: Which lessons can be drawn from a review of existing information services?
SQ3: Which opportunities or challenges can be identified for future success of these services?

1.6 Outline of report

This thesis consists of seven chapters in total. This chapter serves as a general introduction to the topic, introduces the study area as well as other background information, and poses the problem statement, research questions and objectives. Chapter 2 will provide the underlying theoretical framework used to deconstruct the topic into smaller elements and aimed at conceptual understanding of the functionality of information services. Chapter three gives a description of the methodology used in this thesis, with the results of that methodology being presented in chapter four. Chapter five will discuss strengths and possible limitations of this thesis. Finally, the conclusion of this thesis can be found in chapter six, complemented by several recommendations for future research. A list of literature sources can be found in the bibliography, and further information in Appendices A until E.

2 Conceptual framework

This research will be carried out around a modified version of the end-to-end concept, coined by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. (NOAA, 1994), and elaborated by Goddard *et al.* (2001). This concept is originally intended to include social systems modelling into the application of climatic forecasts. It describes relations between climatic states and predictions, forecast information, user components, decisions and outcomes by placing the components in a certain order and assuming interaction and feedback between them, as illustrated in Figure 2.

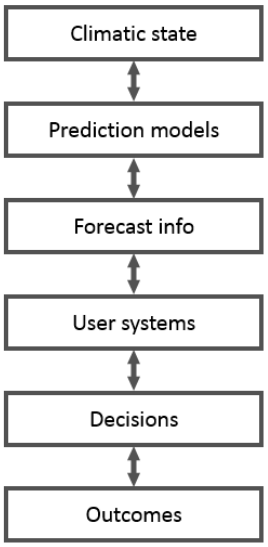


Figure 2: The end-to-end concept. Source: Goddard *et al.* (2001).

This approach requires collaboration between disciplines and encompasses biological, physical, and societal elements (Goddard *et al.*, 2001). Applications designed along the line of thinking of the end-to-end concept perform their functions generally driven by information demand, for the design of specific services for each client (Garbrecht & Schneider, 2007). This approach is effective in fitting together modelling-oriented predictive products to decision-making criteria and end-users (Garbrecht & Scheider, 2007). It uses bottom-up participatory methods which hold potential to tackle implementation problems that have been described previously.

Although this concept intends to provide structure for designing services, this thesis instead reviews the operation and impact of currently employed ones. Therefore two alterations to the original concept have been considered. The first one modifies the concept by removing the blocks of 'climatic state' and 'prediction models'. The suitability of observed climate data and choice of prognostic models will hence not be addressed. Secondly, 'forecast information' will be replaced with 'information', as this study is not limited to information with mere predictive characteristics. Several exemplar factors have been added for clarification to the modified end-to-end concept in Figure 3.

Each factor in a coloured box with cut corners is an exemplar socio-technical factor, belonging

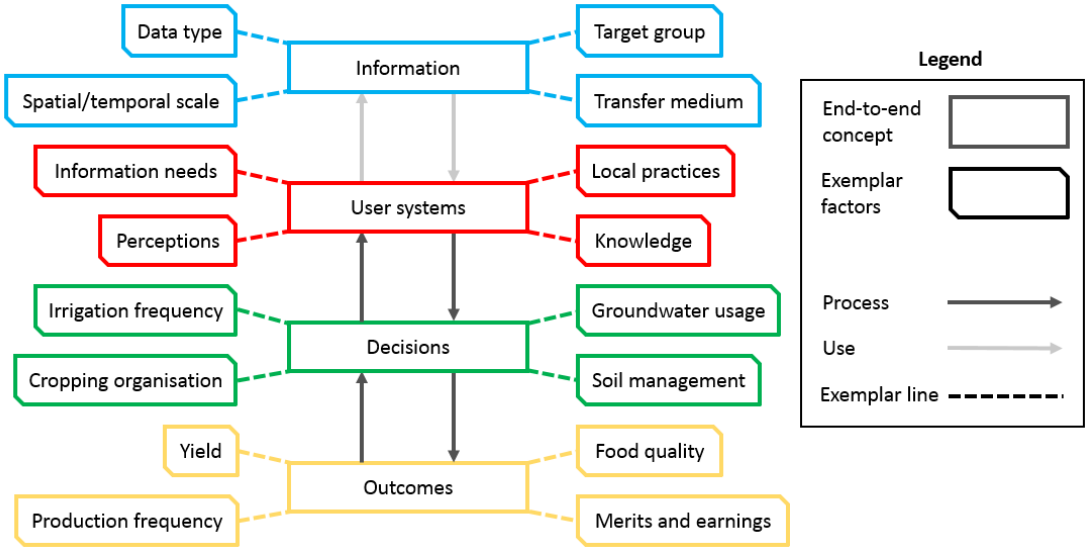


Figure 3: The modified end-to-end concept as used in this study. Adapted from Goddard *et al.* (2001).

to one of the four 'levels' that together constitute the modified end-to-end concept. Blue factors relate to the design parameters of information services, such as targeting services at either subsistence farmers or agribusinesses. Red factors relate to user systems, describing farmers' practices, experience, gender, age and household situation and relate to how their considerations and convictions form the basis for their capacity to act. Green factors describe the wide variety of decisions a farmer faces, e.g. the choice to make excess use of groundwater in arid periods. Finally, yellow factors relate to agricultural production, for example in terms of yield and earnings. Although only four factors of each colour have been presented in the schematic representation of Figure 3, it goes without saying that this scheme is non-exhaustive.

The square coloured boxes of the end-to-end concept are connected with arrows, which are indicating causal processes between the respective components. In this study, the use of information systems is also considered to be such a process, involving the two-way interaction between information and user systems. It has been indicated with grey arrows in Figure 3. Considerations made at a certain level could have cross-level consequences, causing a response, interaction or feedback at a lower or higher level. This system can therefore be seen as a complex web of interconnecting processes, where intervention and feedback co-exist. Taking into account that cultural principles of farmers are known to be of key importance for climate services (Golding *et al.*, 2017), the importance of bottom-up processes and tailoring or co-creating information services should not be neglected.

In Table 1, several exemplar factors have been provided in a non-exhaustive overview based on Figure 3.

Table 1: Exemplar socio-technical factors with their level and some examples

Level	Factor	Example
Information	Data type	Climatic, meteorological or food pricing data
Information	Spatial/temporal scale	Localised data and/or short-term predictions
Information	Target group	Subsistence farmers or agribusinesses
Information	Transfer medium	Television, radio or phone application
User systems	Information needs	Timing and variability of rainfall
User systems	Perceptions	Weather cannot be predicted; climate can
User systems	Local practices	No irrigation until a week after sowing
User systems	Knowledge	Southern wind indicates approaching rainfall
Agricultural decisions	Irrigation frequency	Biweekly irrigation in a 20-minute turn
Agricultural decisions	Cropping organisation	Polyculture, crop rotation or intercropping
Agricultural decisions	Groundwater usage	Quantity and timing of used groundwater
Agricultural decisions	Soil management	Reduced tillage and/or organic fertilizer
Food production	Yield	A high or low rice yield per hectare
Food production	Production frequency	Cultivate rice two or three times annually
Food production	Food quality	Products without pesticide or disease
Food production	Merits and earnings	Livelihood support or long-term investment

3 Methodology

The methodology used for data collection and analysis will be described in this chapter. This methodology section includes descriptions of preparation field work, the data collection and the analysis of acquired data. This study used a qualitative interviewing approach to collect data on field level, and analyses the acquired data using a multi-value Qualitative Comparative Analysis (mvQCA) (Ragin, 1987). The full methodology has been visualised schematically in Figure 4 and will be elaborated in the remainder of this chapter. In the first subsection, steps taken during field work have been described, while the next subsection elaborates on how data has been collected by interviewing. The last subsection describes the way the mvQCA functions.

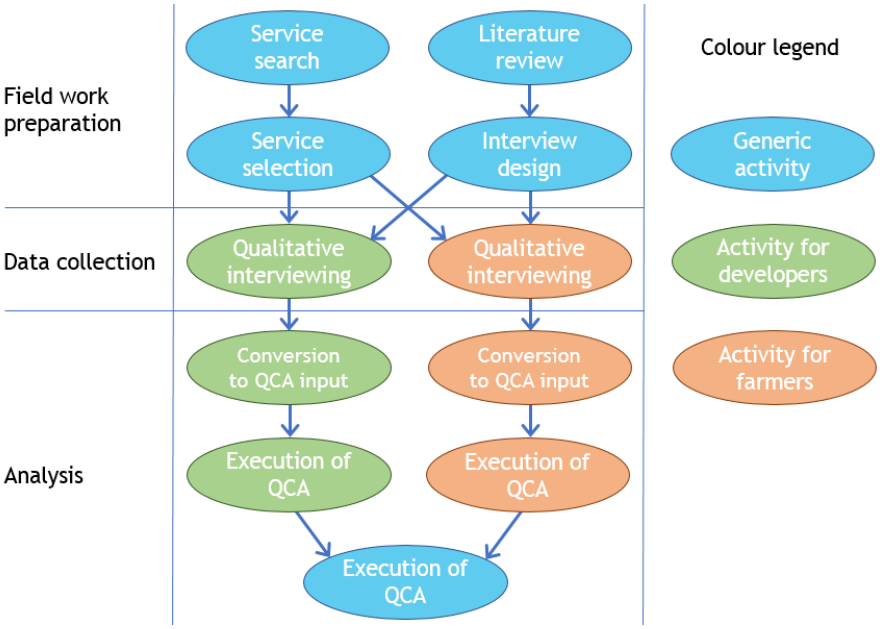


Figure 4: Schematic representation of the methodology. Source: own work.

3.1 Field work preparation

Exploration of relevant services

During preparation of the field work, initially a document review has been conducted using mainly online sources, in addition to a document titled 'Inventory of existing ICT platforms for WaterApps development'. This document has been prepared for and by the WaterApps team as preparation for a design workshop held in the Orion building of Wageningen University on March 18, 2018. The aim of this documentation review was to get acquainted with a number of commonly known information service providers and intermediaries in Bangladesh, gather background information, and start building a database with contact information and a brief description of their service. Part of the database is also an overview of which parties are involved in which service, and how information flows from one developer or intermediary to another, before ending up at the user. However, this study is not necessarily restricted to services directly related to agricultural information. Special focus was also on information providers who are known to be involved in the climatic and market sectors, or are actively involved in disseminating information

among local farmers. Naturally, another important requirement for inclusion in the database is that the provided service could be accessed by users specifically located around Khulna. This is irrespective of whether a user may or may not have the proper technologies or assets required to do so. This database with stakeholders is expected to contribute to answering sub question 2, and the activity of building this database has been continued with renewed insights during the field work phase.

The next step was to make a selection of which services are going to be included in the analysis, a process that ran partially simultaneously with the field interviews described in the next subsection. Starting this, it is initially of vital importance to determine the quantity of services that is going to be included. The tool that is to be used (mvQCA) is powerful in examining middle-sized-N data sets (Herrmann & Cronqvist, 2009), with recommended size $5 \leq N \leq 50$ (Ragin, 2003, p.13). The way mvQCA works will more elaborately be described in the last subsection – for now it suffices to know it is a tool for middle-sized-N data sets. For this study, addressing only up to four information services would not achieve compliance QCA criteria, whereas analysis of more than 50 services has strongly been discouraged during field work preparation for various other reasons. The amount of services in the data analysis being between 5 and 50 is hence appropriate for this study, justifying analysis by means of a mvQCA. For inclusion of a service into the QCA analysis, a shortlist of services has been selected, representing the variability in data types and dissemination media, in pursuit of a comprehensive overview. Data on available types and media have mostly already been retrieved during field work preparation.

Services are eligible to be included in the QCA when their developer is based in Bangladesh, subject to their willingness to be interviewed and to their availability. In the selection it is strived for to have the public and private sectors represented equally often. Also, the selection criteria are aimed at balancing available types of information and dissemination media, to obtain an overview of which information is available for farmers and how it is made available. For this purpose, from all earlier identified services the data type and medium will be written down, so the QCA can (1) encompass all identified data types & media and (2) balance these in its selection. Services will always be excluded from the QCA for matters relating to feasibility. For example, if the developer is foreign-based (e.g. India), not willing to be interviewed or not responding to requests thereto.

Literature review
Next to this, a scientific literature review has been conducted. The focus of this review was to identify factors that in previous or similar studies about information services have proven to enhance or hamper information uptake or use. Because several of these studies may have been conducted outside of Bangladesh or might not necessarily relate to agriculture, it cannot a priori be assumed that found factors will be of similar relevance for the situation around Khulna. Therefore, the factors as identified in literature will serve as the foundation of the design of the interview guides. The idea is to identify to what extend these factors play a role in information use for the farming communities around Khulna. Additionally, this review is expected to contribute towards answering sub question 1.

Interview design
Using the factors retrieved from literature, structured interview guides with open-ended questions have been developed during field work preparation, aimed at interviewing either farmers or service providers and intermediaries. These interviews were used as the primary means of data collection. Structured interviews can be used for data collection in qualitative research,

and provides each interviewee with the same questions in the same order (Kvale & Brinkmann, 2009). groups of stakeholders, farmers on the one hand and information service developers or intermediaries on the other hand, were interviewed using this method. A theoretical maximum of 50 interviews was set, recognizing boundary conditions such as feasibility and available time during field work. It is realistic to assume no more than 50 resource persons are to be interviewed in the allotted time frame. Moreover, this measure has been taken in an attempt to prevent interviews to result in predictable or repetitive output.

The interview questions have been set up in such a way that they connect to the knowledge level of the interviewee, and cover the full range of factors identified in the literature. For farmers, the interviews are centred around their experiences and interaction with the service, and inquire implications for on-farm decision making. Farmers who previously used services but currently abolish them can be interviewed as well, identifying failed services and focusing on reasons for ceasing use. For developers, several questions were included about parameters relating to the design of the service, and they were asked to reflect on the effectivity of their service by naming impacts for farmers or their decision-making. All interview guidelines have been designed in the English language, and are in situ to be translated by an interpreter when an interviewee is not sufficiently fluent in English. The full interview guides can be retrieved from Appendix E.

As farmers and developers have such different backgrounds for which separate interview guidelines had been developed, it was assumed that these two groups would not necessarily provide similar interview output. Therefore it was assumed that for each service a developer and a user had to be interviewed, to allow for comparison and a more critical view on their interview output.

3.2 Interviews during field work

During the field work stage, a total of 27 interviews have been conducted during the months May and June 2018. Interviews have been conducted in the Batiaghata and Dumuria upazila in the Khulna district, as well as in Dhaka, the capital of Bangladesh. Thirteen interviews have been held with farmers and fourteen have been held with information providers or intermediaries. A full list of all interviewees, including location, date and other notes can be retrieved from Appendix B.

Almost half of the interviews (14) have been conducted with service developers or intermediaries, by visiting their office either in Khulna or Dhaka, by sending them an invitation to visit Khulna University, or by using telephone calls or Skype. This group of interviewees consists of governmental authorities, commercial private companies and humanitarian or developmental organisations. These have either already been documented in the list of service providers during field work preparation or added to this list during field work. An additional requirement for broad coverage of the topic was to conduct at least one interview of each possible 'type' of information aimed at farmers, and at least one interview per medium used for dissemination. Available types and media could at this phase already be retrieved from the initial list of services made during field work preparation. These interviews usually took between half an hour and one hour in a one-to-one setting, and each participant was interviewed only once. Four interviews have been conducted in close collaboration with U. Kumar, PhD candidate for the WaterApps project in Khulna. In those interviews, a rather constructive collaboration during joint interviews ensured his interview questions would complement the ones designed in this study – or vice versa.

The other half of the interviews (13) were conducted with farmers, by visiting their villages. Farmers who have been interviewed have been selected using simple random sampling. Interviews were conducted only when the criterium that the interviewee is actually using an information service has been met, and interviews are also subject to the interviewee's willingness to be interviewed. For the record, no sampled farmers refused to be interviewed. In each of the three visited communities, the amount of farmers interviewed varies between two and seven. Most of the farmer interviews took about half an hour and each farmer was only interviewed once. In the Dumuria community, although 39 farmers were asked to participate in an interview, only four interviews were actually held since the majority of the farmers is not using any information services. Although during each of these interviews a significant number of (illiterate) farmers were present, these four interviews only have one participant each. In Batiaghata, 43 farmers were asked to participate, leading to nine interviews with in total eighteen participants. Altogether, 82 farmers have been approached, resulting in 13 interviews with 22 participants.

As stated in the subsection above, it is required to interview a developer and a user from each analysed service. In case no users can be found as follow-up of a developer interview, interview guidelines had to be developed in which a service will be presented to a non-user. These questions address most of the factors for the user interviews and focus mainly on implications for decision-making. The guidelines can also be retrieved from Appendix E, accounting for two conducted interviews in Batiaghata, once with five and once with six participants. It is important to emphasize that during the introduction of the service, the non-users will be given time to discover the contents and possible implications of the service without guidance of the researcher. In an attempt to evaluate the various factors addressed in the interview in an unbiased manner, the user is free to experience the service without external interventions from the researcher or interpreter.

Before each interview started, the participant was asked for approval of recording the interview for research purposes. Using mobile phone built-in sound recording software, the interviews were recorded once consent was given. The raw data was later on transferred to a laptop, and to avoid possible data loss also to a USB flash drive. The raw sound material has been transcribed into written text for 26 of the 27 conducted interviews, following the structure of the interview guidelines. The remaining interview has not been transcribed, as no answers suitable to serve as input for the QCA have been given. Conducting the interviews was expected to contribute towards answering sub question 2 and 3.

In case the interviewee was not sufficiently fluent in the English language, an interpreter was present for translation. Bengali, the most commonly spoken language, is not the same across the country, but subject to local variations in pronunciation and wording. Interpreters all understood the local tongue of the Khulna region; they usually were other members of the Khulna WaterApps team, already acquainted to interacting with and questioning local farmers. In several occasions Khulna university students outside the WaterApps project acted as interpreters (they were local too). These students already had experience in interviewing, because of their previous visits to farmer villages (S. Ahamed), or because of work experience at radio station Bangladesh Betar (M. Mumu). During interviewing, a question from the interview guide would be asked in English and translated into Bengali. After that the interviewee could respond in Bengali. Their response would be translated back into English before the next question would be asked.

3.3 Qualitative Comparative Analysis

Operation of the QCA

A Qualitative Comparative Analysis (QCA) is a technique for data analysis that aims to support conclusions by data set inference (Ragin, 1987). Coined by Charles Ragin in 1987, the original technique, 'crisp-set QCA' or csQCA in short, uses Boolean values (0 and 1) for a phenomenon to indicate if it occurs or not, followed by listing all possible combinations of occurrence in a table. It then, using logical operators and deductive inference, demonstrates which conclusions the data set supports. This technique can be used to illustrate the relationship between combinations of causal factors (like choice for data type and transfer medium) and a certain output (like decision-making). QCA hence uses multiple sets of contributory factors to show causal predictors associated with a particular conclusion or result.

However, the QCA categories cannot always be expressed in Boolean sets. For example, while some services are transferred by conventional mass media, others might be via mobile phone application, neighbourhood posters or locally available newspapers. This range of possibilities cannot simply be incorporated into a dichotomised csQCA, but needs an approach with less narrowly defined input options[2]. Hence, this research will focus on another ramification of QCA, namely the multi-value QCA or mvQCA (Cronqvist, 2003, 2005). In short, input in a mvQCA allows for multiple values per category, in contrast to the csQCA. In a mvQCA, each factor can be represented by a natural number $\aleph = 0, 1, 2, \ldots$, with the amount of numbers depending on how many elements the factor consists of. This analysis technique hence allows for flexible input dimensions beyond binary values, and it has been chosen as tool because of its strength in multinomial condition data handling.

The input values will (as in csQCA) be converted in a so-called 'truth table'. This table lists all possible combinations of the observed input values: each row represents a possible combination, a so-called 'case'. For mvQCA it is still a requirement that the output is dichotomised (Cronqvist & Berg-Schlosser, 2008, p. 84). In this study, each row represents an information service. In Table 2 below, three types of transfer mediums and two data types have been considered as an example of analysis. Regarding transfer mediums, television has been assigned value 0, mobile applications value 1 and radio value 2. For data types, the value 0 for agricultural data and 1 for weather data have been assigned.

Table 2: Truth table illustration for mvQCA

Service	Transfer medium	Data type	Success
Agri-tv	Tv	Agricultural	Yes
Weather app	Application	Weather	No
Agri radio	Radio	Agricultural	Yes

Service	Transfer medium	Data type	Success
Agri-tv	0	0	1
Weather app	1	1	0
Agri radio	2	0	1

[2]Technically, crisp-set QCA can be used in this way by splitting multinomial conditions into multiple binary ones. This would create additional combinations in the QCA truth table, which are impossible to occur in reality. A scientific debate as to whether or not that is the right approach is going on, for which Schneider & Wagemann (2012), p.255, Vink & van Vliet (2013), p. 210, Thiem (2013) and Haesebrouck (2016), pp. 6-11 can be consulted.

The rows indicated with 'Agri-tv' represents a hypothetical service with the combination of agricultural data transferred by tv, the one below the combination of weather data and an application. The bottom one represents a radio program combined with agricultural information. The fourth column in this case represent the outcome, in this case success. On each row, a 1 is assigned if success is always the result of the particular combination of causal factors on that row. A 0 is the result of absence of success on a row. From this illustrative tables it can be deducted that success is the result of providing agricultural information, irrespective of the medium. mvQCA is hence capable of capturing the relation between various causal factors and an associated outcome, as described by Haesebrouck (2016). While the data from the top half of Table 2 can be derived from the interviews, they need to be converted into numbers as in the bottom half of Table 2 to enable QCA functionality. A more detailed description of these conversions can be found below.

Success definition
In this thesis, the success of an information system in the QCA can been determined by three requirements. Firstly, a potential user must have sufficient access to the information that is being provided, well in advance, and within the decision-making lead-time (Easterling & Mjelde, 1987). Secondly, it is of vital importance that a user is able to understand and interpret the information he or she gets. Provided information is therefore required to support the decisive capacity of the user and has to assist the user in undertaking certain action: this will be indicated with the term actionable for the remainder of this thesis. Actionable knowledge has by Geertsema *et al.* (2016) been defined as being (1) context-specific and (2) assisting decision-making of stakeholders. The third and final requirement is that the provided information actually has to be acted upon for on-farm activities. The distinction between the second and third requirement has been made because in theory a farmer could be provided with actionable knowledge without actually acting on it. In this, there lies a distinction between passively obtaining actionable information on the one hand and attempting to connect the information to farming activities on the other. Failure to comply with one or multiple of these requirements resulted in the service being treated as 'failure'. As one could observe through the way success and failure have been defined, these three requirements have been established such that the success rate of an information service is of binary nature. This is in accordance with an earlier mentioned criterium for output dichotomisation (Cronqvist & Berg-Schlosser, 2008, p. 84).

There are parallels between the modified end-to-end concept and the requirements of success. They attempt to connect the consummation of a service to the conceptual frame. Firstly, the access argument runs well in parallel with the 'use' process, albeit access being only the top-down informational provision to the user. User feedback from user systems back to the information level is not considered part of the user having access to information. The second criterium, actionability, can be considered an internal process within the block of user systems. Users have a form of qualitative mental models in their minds, based on their experiences, customs and hearsay (Goddard *et al.*, 2001). These mental models are expected to filter incoming information, shaping it into an interpretation that describes to what extent incoming information is effective (Goddard *et al.*, 2001). Thus, when filtered information corresponds with a users' customs or experiences and is congruently able to assist his or her decision-making, the actionability criterium has been passed. Thirdly, the action criterium can be used to assess whether or not a farmer actually based decisions on available information, making the impacts of the decision-making process more visible. This action process can be considered to run parallel to the top-down arrow pointing from user systems to decisions in the conceptual frame.

Interview input conversion & QCA execution
After interviewing, the gathered responses have been converted to enable QCA execution. The interviews have additionally also directly been used to aid in answering sub questions without QCA interventions, which for readability purposes has not been visualised in Figure 4. Setting up input parameters for the QCA, an Excel spreadsheet was used. After transcription of the sound recordings, raw data in the shape of written sentences were available. The interviews have been set up such that almost all questions centrally address one factor identified from literature for one case. Hence, most answers will eventually be converted into one QCA input digit. First, interview responses will be summarized into one or two keywords, like in column 2 and 3 in the top half of Table 2. These keywords are chosen such that they aim to represent the interview response as well as possible, and are hence subject to interpretation. When for an addressed factor the interview responses of all cases have been summarized, the conversion into the bottom half of Table 2 can be made. Farmer and developer responses were kept separately for reasons described above. Therefore two separate tables were made, holding factorial information in its columns and service names in its rows. For execution of the QCA the publicly accessible software tool Tosmana (version 1.5.4.0) has been used (Cronqvist, 2017).

Three QCAs have been carried out, one resulting from interviews with developers and the second one resulting from farmers' interviews. The third one needs a more elaborate introduction: it combines insights from the first two and furthermore includes independent observations. This QCA is hence aimed at visualising information services' procedures and operations from an outsider's perspective and attempts to eliminate possibly conflicting QCA output – or if not possible, to clarify it. The third QCA, henceforth called 'combined QCA', has been executed after gathering results from the first two.

4 Results

4.1 Available information services

This study has found a total of 198 services, developed or disseminated by 118 parties using a variety of media. For a full overview, Appendix A can be consulted. Four types of information have been identified in this thesis, i.e. weather information, emergency warnings, agricultural advisories, and market prices. Weather information consists of forecasted, current or historical data sets of predominantly rainfall and temperature, although other parameters like humidity or wind velocity are also disseminated (e.g. on the AccuWeather website and application, see Appendix A). Emergency warnings include notices of heavy rainfall, squally wind, flooding, droughts and heat waves (e.g. in push notifications by the BMD Weather App or FFWC flood warnings, see Appendix A). Agricultural advisory is a broad term and relates to information on agricultural activities: crop growth in various stages, accounting for seasonality, seeding, pesticide, fungicide and fertilizer application, plant disease remedies and irrigation techniques. Examples of related services include the assortment of mobile applications designed by the Bangla Public Library on crop cultivation and tv programs like Krishi Dibanishi and Krishi Songbad. See Appendix A for more agricultural advisory services. Lastly, market information relates to food or agricultural input pricing on local markets or other places (e.g. via mobile application dkrisi, see Appendix A).

The general approach of this subsection (4.1) is to identify via which media information is disseminated in peri-urban Khulna, and to examine which services are available via which media. Based on the occurrence of a service and its current use for disseminating information, it may in subsections 4.3 or 4.4 be selected for closer examination. This subsection builds on findings by Omogor (2013) and Hasan *et al.* (2017) who state that radio, tv and extension work represent traditional major information channels for the agricultural sector. Thus an attempt was made to identify which television programs, radio broadcasts and extension services are available, and on which channels or via which providers. Taking into account that access to internet is increasing and the amount of mobile subscribers is on the rise (Harpur, 2017), several mobile phone applications have also been examined. Newspapers, although regarded as conventional mass media, have after examination not been included in this subsection because they have the lowest reach of all media in Khulna (Ashraf, 2018) and since they have only been found to disseminate exactly the same weather data as other larger media (interview 3). Informal information from e.g. local business men, neighbourhood posters or peer farmers has also not been included as these sources may be highly fragmented or only available on village or household level. In the following paragraphs, firstly the roles of the traditional mass media television and radio will be discussed, followed by a description of dissemination through agricultural extension and mobile applications including other online sources.

Information available via television

Illustrating the large range of television, several studies claim the majority of their respondents from farming communities watch television for obtaining weather or agricultural information (Alam & Haque, 2014; Khan *et al.*, 2017; Ashraf, 2018). This is the result of a rapid expansion of access to tv in the rural areas of Bangladesh: between 1999-2011 rural access increased drastically from 24 to 67% of inhabitants (BBC, 2012). The host of the Mati o Manush program stated that the current number of tv connections is still increasing (interview 8), possibly resulting from Bangladesh's high economic growth over the past decade (Economist, 2017).

The most popular Bengali tv channels are Channel-i, ATN Bangla and Bangladesh Television

(BTV) (BBC, 2012). As of 2016, 37 Bangladeshi satellite TV channels exist, two of them public and 35 private ones (BTRC, 2016). In addition, more than forty channels are Indian market-based, broadcasting in both Hindi and Bangla (Khanam *et al.*, 2014). The most watched Indian channels in Bangladesh are Zee Bangla, Star Jalsha and Star Plus, with possible reasons to prefer Indian channels over Bengali ones include low-quality programmes or lengthy advertising times (Khanam *et al.*, 2014). Weather forecasts on all Bengali tv channels originate from the Bangladesh Meteorological Department (BMD), the government body responsible for meteorological forecasts and seismological observations (interview 3). Bengali tv channels also broadcast a variety of agricultural programs (Alam & Haque, 2014; Jannat, 2015).

In India, two parties are involved in weather forecasting: the Indian Meteorological Department (IMD) and Skymet Weather Services. The IMD, under the Ministry of Earth Sciences (MoES), is reportedly the prime public agency in matters involving seismology, meteorology and allied fields and provides climatic and weather services to the public (Laskar, 2017). The IMD uses national public TV broadcaster Doordarshan for dissemination of farmer advisories based on weather information (MoES, 2016; Attri *et al.*, 2011). Doordarshan also broadcasts weather forecasts in the Bangla language on DD Bangla. The IMD is currently in competition with Skymet Weather Services, the main private weather agency (The Economic Times, 2015). Skymet disseminates its forecast via its website and several newspapers and tv-channels, like Zee News and APB News, and broadcasts also in Bangla (Skymet, 2018).

An example of a weather forecast on Bengali tv is the one in Figure 4 on ATN News for May 28, 2014. It gives an overview of what a typical forecast with data provided by the BMD would look like. For Khulna, the forecast indicates a low of 14 degrees and a high of 33 degrees. A forecast of similar setup is provided by Skymet Weather, albeit for Calcutta, an Indian city close to the Bengali west border. The Skymet forecast will be translated to Bangla when broadcasted on tv channels of Bengali-speaking Skymet customers.

Figure 5: A typical weather forecast from ATN News (left) and Skymet (right). Retrieved May 15, 2018, from youtube.com/watch?v=erS-hWBVKw8 and youtube.com/watch?time_continue=1&v=ZYSrhIUuK3Y

In addition to weather forecasts, several agriculturally-relevant informative shows are broadcasted, for example on BTV, Channel-I, Bangla Vision, Boishaki Television and GTV (Alam & Haque, 2014; Jannat, 2015). On DD Bangla, the tv-show Krishi Darshan (Agricultural Philosophy) is broadcasted in cooperation with the Ministry of Agriculture (MoA) of India and Agromet,

a subdivision of the IMD (MoES, 2018). This program is aimed at 'educating' and 'informing' farmers about improvements of their agricultural productivity (Manisha & Deb, 2009). Similar shows on Bengali television are often recorded on-field and transmit farmers' stories, experiences or techniques. Bangladesh's oldest agricultural show, Mati o Manush, literally meaning 'Soil and Man', has already been broadcasted on BTV on a daily basis for more than 35 years. According to the program's host, Mr. Siddique, the program is apart from its long history also unique as it is the only agricultural television show promoting mango and dragon fruit orchards for the last 20 years (interview 8). The show is shaped in an on-field conversation between the host and various farmers, and addresses farmer problems and successes. The program also presents available technologies, and aims to be a catalyst between farmers and other stakeholders like business men or extension officers, by means of promoting farmer entrepreneurship development (interview 8). Information contents are government-validated without user monitoring, but instead the program is equipped with an informal feedback system on-field, with input from other viewers, extension officials or developmental organisations (interview 8).

In Table 3, a summary of relevant television programmes available in Bangla in the Khulna area can be found.

Table 3: Summary of relevant television programmes available in Khulna

Channel(s)	Programme
BTV	Agriculture of Bengal-Banglar Krishi Agriculture News-Krishi Songbad Agriculture Round the Clock-Krishi Dibanishi Country and Population News-Desh O Jonopoder Khobor Soil and Man-Mati o Manush Unending Bangla-Obiram Bangla Weather forecast
Channel-I	Agricultural Budget-Krishi Budget Agricultural News-Krishi Bartha Agricultural News-Krishi Songbad Agriculture Round the Clock-Krishi Dibanishi Soil and Man in the Heart-Hridoye Mati o Manush Call of Soil and Man in the Heart-Hridoye Mati o Manusher Dak Weather forecast
Bangla Vision	Green Bangla-Shaymol Bangla
Boishakhi Television	Agriculture and Life-Krishi o Jibon Seven Colours of Success-Shat Rong
GTV	Green Bangla-Shobuj Bangla
DD Bangla (Doordarshan)	Agricultural Philosophy-Krishi Darshan Weather forecast
ATN Bangla	Agriculture Documentary-Krishi Bishoyok Pramanno Anushthan Unending Bangla-Obiram Bangla Weather forecast
Zee News	Weather forecast
ABP News	Weather forecast
Somoy	Weather forecast

It can be concluded that agricultural television in Bangladesh has a large reach and a wide variety of available channels and programmes. Not included in Table 3 are emergency warnings, as they are not part of regular broadcasts or programs. Meteorological warnings will be issued a few days before the expected disaster by the Storm Warning Centre (SWC), a subdivision of the BMD. Flood warnings originate from the Flood Forecasting and Warning Centre (FFWC), a subdivision of the Bangladesh Water Development Board (BWDB).

Information available via radio
Radio, another traditional mass medium, has also been mentioned by Omogor (2013) to be used for information dissemination in rural areas. To enable legal radio broadcasting, the Bangladesh Telecommunication Regulatory Commission (BTRC) issued thirty licenses for FM channels in Khulna, of which 28 private and two state-operated (BTRC, 2016). Still, in 2011 only 15% of the Bengali population was reported to listen to the radio every seven to ten days (Nielsen, 2011). Other studies found similar results: for 107 out of 110 respondents in the Mymensingh district radio turned out to be of no use for farm information dissemination (Khan *et al.*, 2017), while a study by Hasan *et al.* (2017) found in the Khulna and Rajshani divisions only 7% of agriculturists to listen to radio farming programmes.

The Bengali state-operated radio channel is Bangladesh Betar, often abbreviated to BB (Hasan *et al.*, 2017). The Khulna branch of Betar obtains its information via the government agencies Agriculture Information Service (AIS) and BMD and broadcasts every morning from 6:25 until 6:30am (summer) or from 7:55 until 8:00am (winter) the program Krishi Samachar. Every afternoon, they broadcast Chashabad live from 6:10 until 6:50 pm. The morning show is meant to provide farmers with a short advisory for the day, while the evening program is more in-depth and longer. Each broadcast of Chashabad is about two topics, of which agriculture is always one, and the other varies between fishery, forestry or livestock (interview 13). AIS and Betar organise a joint quarterly meeting, and select a number of topics and expert speakers. Speakers are for example local DAE staff, Khulna university professors (from the disciplines agrotechnology, fisheries or forestry) or local school teachers. AIS is responsible for this process and the selection of speakers, and also offers annual public-speaking trainings to their speakers (interview 13).

Bangladeshi farmers also listen to radio from India, broadcasted in Bangla. Indian public radio All India Radio (AIR) broadcasts weather-based agricultural advisories made by IMD (MoES, 2016; Attri *et al.*, 2011). Several AIR channels broadcast in the Bengali language as of 2018, among which AIR Kolkata, Kurseong and Siliguri (AIR, 2018a). In 2004, AIR has expanded its agricultural programming in collaboration with the Indian MoA by broadcasting Kisanvani (Farmer's Voice), updating farmers on daily market rates and weather reports (Prasar Bharati, 2012b). Out of the 96 AIR channels broadcasting Kisanvani, only two of them, AIR Santiniketan and AIR Murshidabad, broadcast in the Bengali language, from their stations in Calcutta, West-Bengal (Prasar Bharati, 2012a; AIR, 2018b).

In Table 4, a summary of relevant radio programmes available in Bangla in the Khulna area can be found. It can be concluded that agricultural radio in Bangladesh has a low reach and a small variety of available channels and programmes. Not included in Table 4 are emergency warnings, following the same reasoning as for television programming.

Information available via agricultural extension
Mobilization of human resources is an important mechanism that allows farmers to receive agricultural information on a personal level. A general definition for agricultural extension would be ''the delivery of information inputs to farmers" (Anderson & Feder, 2007). Effectuating advisory dissemination and trainings, the Bangladeshi national government finances the DAE and its associated local upazila offices and officers. The local DAE offices operate by obtaining information from a higher government level and consequently engaging with farmer communities, organising field days with trainings, schooling and live demonstrations. Topics they provide advisories for

Table 4: Summary of relevant radio programmes available in Khulna

Dissemination channel(s)	Programme
Bangladesh Betar, Dhaka	My Country My Soil-Desh Amar Mati Amar Agricultural Affairs-Krishi Samachar Green Field-Shobuj Prantor Green Crop-Shoshho Shaymol My Country-Amar Desh
Bangladesh Betar, Khulna	Agricultural Affairs-Krishi Samachar Cultivation-Chashabad
AIR Kolkata, Kurseong and Siliguri	IMD weather-based agricultural advisories
AIR Santiniketan and Murshidabad	Farmer's Voice-Kisanvani IMD weather-based agricultural advisories

include advance technology, irrigation techniques, pesticide, fungicide and fertilizer application. Another type of disseminated information is an agricultural advisory based on emergency warnings for occurring calamities like floods, droughts, cyclones, and heat waves (interview 9). The DAE is also involved in a process of selecting and promoting improved crop varieties, which for the coastal regions could entail researching varieties with a higher salinity tolerance. A local Batiaghata farmer reported that he regularly asked for inquiries at the DAE officers for current market prices. He also claimed he would sometimes sell his paddy seeds to the DAE, which purchases it at a subsidized (higher) price for the purpose of commencing their selection process for improved varieties (interview 22). Although the DAE is known to experience some capacity problems, they are also the sole service provider in Bangladesh combining a large network with a personal approach (interview 14).

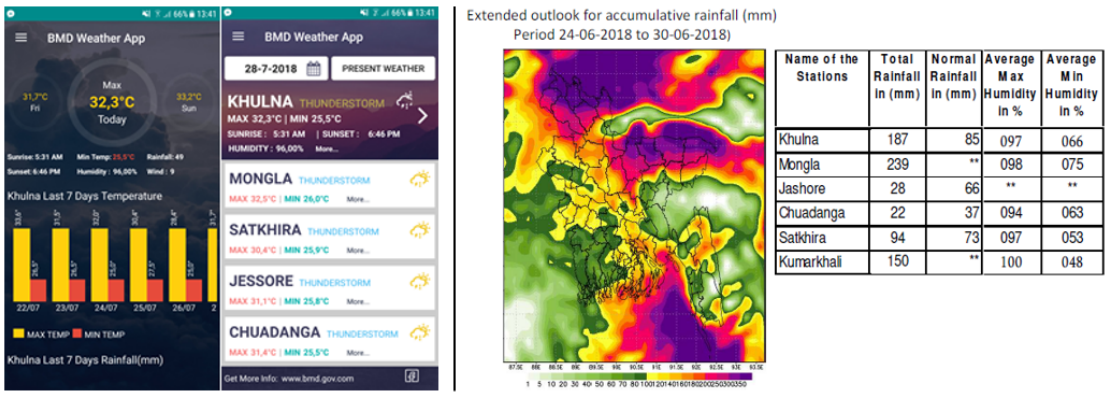
As a more recent development, the DAE in Batiaghata started in close cooperation with the Climate Services for Resilient Development (CSRD) and WaterApps projects to disseminate weather-related information to farmers (interview 14). Another ongoing project, Blue Gold, is involved with the DAE in organising at least 1000 Farmer Field Schools (FFS) in the coastal regions of the Khulna and Barisal divisions (Blue Gold, 2018). These schools aim to disseminate cultivation techniques for rice, fruits and vegetables to increase productivity (Blue Gold, 2018). Blue Gold is also organising modules aimed at training DAE staff, so-called Training of Trainers (ToT) modules.

Information available via internet & mobile applications

Driven by a steady rise of mobile subscribers, the amount of internet users has grown strongly in Bangladesh over the past few years, and is expected keep to growing in the near future (Harpur, 2017). Official government numbers indicate a near tripling of internet subscribers (31 to 83 million) and near doubling of mobile phone subscribers (88 to 149 million) during the period of February 2012 until February 2018 (BTRC, 2018). Handheld phones decrease information and communication costs for poor inhabitants of rural areas, not only providing opportunities for access to agricultural information, but also for using IT in extension systems (Aker, 2011). Emergence of such technology has globally already lead to large availability of mobile applications. Bangladesh is no exception - a quick search for 'agriculture Bangladesh' in the Google Play store (Google Play, 2018) results in 249 available applications (note that the algorithm may include irrelevant ones). Furthermore it's worth mentioning that several information providers or intermediaries (e.g. the governmental organisation AIS) are actively disseminating their products on the internet, using their own website, Facebook page, Google+, Youtube, or even Instagram account. It is nearly impossible to describe this multitude of agricultural websites and applications in detail in one subsection, so instead three developers and their products are highlighted

in the next paragraphs. These have been selected for they represent (1) both public and private parties, (2) small and large organisations and (3) a wide variety of available types of information.

Recently, national weather forecaster BMD has launched a mobile application, the BMD Weather App (in English). The BMD measures a variety of meteorological parameters at more than 200 of their automatic weather stations (AWS) across the country and additionally receives climatic information from nearby countries on a three-hourly basis (interview 3). Using these data as input for their meteorological models, the BMD can predict the weather in Bangladesh and provide storm warnings through their SWC. The BMD weather app is not yet fully functional at time of writing this thesis. It features temperature and rainfall forecasts up to two days in advance and recorded up to seven days in the past, and daily dawn and dusk times, humidity and wind information for all major locations in Bangladesh. Two screenshots of the application can be retrieved from Figure 6. Apart from the via national mass media, the BMD is also known to spread its daily weather forecast via its website (bmd.gov.bd) and via a weekly online and printed document known as the Agromet bulletin (both available in English and in Bengali). The Agromet bulletin is designed to inform farmers about weather-based agricultural advisories (interview 3). Its contents are also disseminated by local DAE officers (interview 3). Two screenshots of the bulletin can be retrieved from Figure 6.



Name of the Stations	Total Rainfall in (mm)	Normal Rainfall in (mm)	Average Max Humidity in %	Average Min Humidity in %
Khulna	187	85	097	066
Mongla	239	**	098	075
Jashore	28	66	**	**
Chuadanga	22	37	094	063
Satkhira	94	73	097	053
Kumarkhali	150	**	100	048

Figure 6: Two screenshots taken from the BMD Weather App (left) and two from the Agromet bulletin (right). Retrieved July 28, 2018 and June 24, 2018, respectively.

Another relevant application is the e-Krishok service basket, designed in 2008 by the private developer Bangladesh Institute for ICT Development (BIID) headquartered in Dhaka (New Agriculturist, 2015). This service includes several modules for agricultural development, including an agricultural extension service, a farmer business model and a tool with basic nutritional information. Although designed like a mobile phone application, it also includes the option to make a phone call and get directly in touch with an expert. According to the CEO of the BIID, the costs of their service are small and negligible for farmers, and the service basket has been developed incorporating user needs and following human-centric design (interview 2).

Lastly, the mobile application dkrisi (*d* stands for *digital*; *krisi* means *agriculture*) is being highlighted here. This service is being presented here as it is a counterbalance of applications by supposedly large organisations, like the national government and private institutes. dkrisi is developed by Mr. R. Islam from Electrosys ICT Ltd., and provides peer farmers with cultivation

information, market rates and weather data. The application is not fully completed yet and still a prototype at time of research. It has been developed following the convictions that 'technology is the best solution for agriculture', 'farmers are too much dependent on the middle men' and 'weather conditions are changing fast' (interview 5).

4.2 Factorial overview

For the design of the interview guidelines and to enable data generation for the QCA, a literature review has been conducted. This review is aimed at the identification of factors that in previous or similar studies about information services have proven to enhance or hamper information service use, a literature review has been conducted. The factors mentioned below can be subsumed under four categories: target group, design considerations, interaction between service and user, and response. The full list of identified and categorized factors can be retrieved from Table 5 below. References for each factor in Table 5 can be retrieved from Appendix C. Factors in italic have been retrieved from literature but will only be addressed in this thesis outside of the QCA. The relevance of each factor in Table 5 will be addressed in the following paragraphs.

Table 5: Factorial overview

Category	Factors in developer interviews	Factors in farmer interviews
Target group	User gender, age, education, farm experience, farm size	User gender, age, education, farm experience, farm size
Design considerations	Design strategy & user feedback, type of data, transfer medium, monitoring users & info, costs	User feedback, type of data, transfer medium, costs
Interaction	*Performance & ease of use*	*Performance & ease of use*
Responses	*User habit, peer recommendation, knowledge,* decisions, *outcomes*	*User habit, peer recommendation, knowledge,* decisions, *outcomes*

Concerning the target group of information services, various studies have been found to address demographic user aspects. For example, Rashid *et al.* (2016) report that age, education, gender, farming experience and farm size have been set as independent variables in their study. These factors are assumed to influence empowerment of Bangladeshi farmers through e-agriculture, a field relating to digital agricultural services and information delivery. These demographic elements are important in observing the target group of an information service.

A study by Rose *et al.* (2016) identifies fifteen agents to be influential for information uptake by farmers in the UK. Among their 'core factors', which directly influence the behavioural intention of the user, performance expectancy, ease of use, peer recommendation, cost and habit are found to be mentioned most often by respondents. Out of these five only cost is an independent factor since the other four are subject to modulation by e.g. user age or gender, which might disturb QCA results. Hence the choice was made only to include costs in the QCA, while the other four, nonetheless valuable and interesting factors, will only be addressed in this thesis outside of the QCA. Additionally, user age and IT education have in the same study by Rose *et al.* (2016) been found to influence the aforementioned five factors independently. In this thesis, user age is addressed but IT education is not, since Bengali smallholder farmers are assumed to not have IT education of comparable magnitude to English farmers. Instead, education in general

is addressed, expressed in years of formal schooling, partially due to a study by Carayannis & Sagi (2000) that also mentions user age and education to be influential for information adoption propensity.

Analysing design considerations a developer is facing before and during implementation of a service is the next step. Addressed factors mainly relate to how developers involve users in their service and how the information is disseminated to them. Islam *et al.* (2013) mention that different types of information (e.g. weather forecast, emergency warnings) are disseminated to farmers, using a variety of media. Perceived ownership and involvement in the design process of information services have been reported to increase end-user commitment (Hirschheim, 1985; Thong, 2001). Golding *et al.* (2017) acknowledge that the incorporation of user needs in developing climate services remains a scientific challenge, and state that understanding of economic and social situations should always precede development of climate services. In this thesis, user involvement in design and incorporation of user needs will be addressed under factor 'design strategy'.

Additionally, Chowdhury (2005) mentions lack of feedback from end-users as a reason for services not being satisfactory. Qiang *et al.* (2009) described that further deployment of ICT-based information services can be limited by among others the fact that monitoring systems are not (fully) in place. From the literature it becomes ostensible that developers are possibly overlooking the importance of user engagement while designing their services, adding 'user feedback' and 'monitoring systems' to the list. Monitoring has been split up into two factors: monitoring the amount of active users is the first one, and monitoring which information is mostly being taken up by them the second. In this, active users are involved in taking up information rather than merely having access to it. For example, someone subscribed to a newspaper or private television channel without consulting them is considered a passive user, while someone reading that newspaper or watching the channel is considered an active one.

Goddard *et al.* (2001) argue that exposure to climate services possibly influences user knowledge levels, agricultural decisions and on-farm outcomes. The reasoning behind that has been described more elaborately in the section Conceptual framework. Likewise, user knowledge, decisions and outcomes have been considered to be interesting as factors in this thesis. During the interviews they have been used to stimulate developers to reflect on the expected or experienced consequences of information provision for farmers. Similarly, they can be used in farmer interviews to indicate impacts of services for agricultural communities. Considering the definition of a successful service as posed in the section Conceptual framework, it is not more than logical that the factor 'decisions' has been appointed as determinative for the success of a service in the QCA.

4.3 QCA analysis & results

Procedures

Eight services have been selected for inclusion in the QCA process. An overview of them can be retrieved from Table 6 below, with each service including the name of the developer and a short description. They have been selected out of almost 200 identified services to in order to represent a wide range of available information, encompassing six identified transfer media (tv, radio, print media, personal communication, phone calls, phone applications) and four identified information types (agricultural advisories, emergency warnings, market information and weather forecasts). These services allow for a suitable amount of cases to be studied by means of a mvQCA ($n = 8$),

given the guidelines of Ragin (2003, p. 13) recommend a minimum of five cases. Information services available from internet (from webpages or social media accounts) have not been included in the QCA, since they were often found to disseminate the same information via a mobile application too, owned by the same developer. Examples are the BMD Weather App and BMD website, AIS application and its social media, and the Ajkerkrishi application and website; see Appendix A for others.

Three QCAs have been carried out, one where interviews with developers determine the scores and another one resulting from farmers' interviews. The third one is performed with scores which combine insights from the interviews and my observations. This QCA is hence aimed at visualising information services' procedures and operations from an outsider's perspective and attempts to eliminate possibly conflicting QCA output – or if not possible, to clarify it. The third QCA, henceforth called 'combined QCA', has been executed after gathering results from the first two. Most importantly, the evaluation of success of the services is based on the combined opinions of the interviewees and my own observations.

Table 6: Information services included in the QCA

Information service	Developer	Short description
e-Krishok	Bangladesh Institute for ICT Development (BIID), private	Mobile application combining agricultural advisories with farm business models and nutritional tools. Includes phone call options
BMD Weather App	Bangladesh Meteorological Department (BMD), public	Mobile application forecasting weather parameters
Agromet bulletin	Bangladesh Meteorological Department (BMD), public	Formatted like a (digital) document, this weekly service provides weather forecasts and advisories
Krishi Samachar	Agricultural Information Service (AIS), public	Morning regional radio program with agricultural advisories
Mati o Manush	Bangladesh Television (BTV), public	Daily agricultural advisory television program
DAE agricultural advisories	Department of Agricultural Extension (DAE), public	Agricultural advisories disseminated by DAE officer field visits
DAE emergency information	Department of Agricultural Extension (DAE), public	Storm and other emergency warnings disseminated by DAE officer field visits
dkrisi	Electrosys ICT Ltd., private	Mobile application combining cultivation information, market rates and weather information

Results
Three QCA data tables have been visualised in Appendices D.1, D.2 and D.3, for the developers', farmers' and combined QCA, respectively. One striking result is that all developers except one consider their own service successful. The Agromet bulletin, designed by the BMD, is the only one not living up to its expectation, according to its developer. The bulletin faces several serious problems, e.g. the missing translation of weather forecasts into advisories useful for farmers. It focuses primarily on meteorological parameters but hardly provides agricultural advice, making it difficult to understand for farmers. In addition, there are dissemination problems as farmers often do not have an internet connection, or physical dissemination by DAE is insufficiently frequent in some areas. Although the other seven developers claimed their users have sufficient access to and understanding of the provided information, the farmers QCA largely refutes these claims. For farmers, only three out of eight services are considered successful, i.e. the tv program Mati o Manush and the agricultural and emergency information provided by the DAE.

The five services considered a failure by farmers each have their own (set of) problems. To start off, no users could be found for these five services (more detailed information will be presented in the Discussion section). After initial exposure of the services to volunteering non-users, some reasons for failure became apparent (interview 12 & 13). For example, the BMD Weather App has been developed in the English language, so couldn't be understood by any of the farmers the application has been presented to. dkrisi, e-Krishok and the radio broadcasts were not considered successful because the farmers claimed to already have retrieved the information via alternative channels or from experience ('the moon and the stars' and 'we are experienced farmers', interview 12).

Further results indicate that only two services, e-Krishok and the BMD Weather App, target young farmers by providing mobile applications, according to developer interview responses. However, these two claim not to target users with a particular gender, education, experience or farm size. Perhaps even more striking is that the other six service developers claim not to target these specific farmer groups at all. Tailoring information to individual or farmer group needs is thus barely practised by these eight developers. Considering the QCA input, a developer claiming to target users of specific age has been indicated with a '1' for the age factor, while not targeting (written as 'n.a.' in Appendix D.1) has been indicated with a '0'. The age factor categories are not the same for the farmer QCA, where a '0' for age represent a user between 20 and 29 years old, a '1' a user between 30 and 39 years old, and a '2' a user older than 40 years.

Most observed services have been developed using the classical top-down method, by which information is provided without involvement of users or their requirements. dkrisi is the only service claiming to incorporate farmers' information needs into the application, as the developer is also a farmer himself, who claims to maintain close contact with peer farmers while facing similar agricultural problems. e-Krishok and Mati o Manush have also had interaction with farmers during development of their services, but do not take user needs systematically into account, albeit for different reasons. For Mati o Manush, farmer contact during the recording of the program is informal, not obtained at a steady frequency and not decisive as most information originates from and is approved by the Ministry of Agriculture. For e-Krishok, user needs are not fully incorporated into their service because the developers do not follow the complete process of design-thinking, but may skip essential steps. Mati o Manush and e-Krishok have therefore been assigned a collaborative design strategy in the QCA, instead of top-down or bottom-up.

User feedback is only given to Mati o Manush and DAE officers spreading agricultural in-

formation, according to the developers. Users indicate conflicting feedback inputs: according to them, only DAE officers receive it for both dissemination of agricultural and emergency information. The differences can be explained by choice of interviewee: the DAE officer that has been interviewed about DAE emergency information is leading the Bathiaghata regional office and hence, since she's higher up in the hierarchy than the field officers, may not directly retrieve feedback from farmers. On the other hand, DAE officers active at field level regularly retrieve feedback from the farmers they engage with when visiting their villages. Regarding Mati o Manush feedback, chances that the farmer interviewed for this thesis also happens to provide feedback to the tv program are naturally very small, as the main feedback mechanism for Mati o Manush is on-field interaction during recording.

Another conflict occurs in the QCA tables when observing informational costs. In principle, information from any of the eight services is free to access, but users do have to pay a fee for electricity or networking costs. This makes only the DAE services truly free for users, while the other services are subject to low costs for access.

In the combined QCA, the conflicting values for feedback and costs have been harmonised to the situation most plausibly occurring in reality. The targeting of young farmers by e-Krishok and the BMD Weather App has been maintained in this table, as it is realistic to assume e-Krishok and the BMD are targeting this group by choosing a mobile application as medium. Especially the younger generation who grew up with technology are assumed to have higher adoption rates to novel techniques, and have increased access to smartphones and associated assets. In this table, the presence of feedback systems has been assigned to Mati o Manush and both DAE services. The mobile applications, Agromet bulletin and Krishi Samachar do not have any feedback options installed or otherwise enabled. Concerning costs, the total costs for the user including network access and electricity have been used in this analysis. Success rates are per definition in accordance with those observed in Appendix D.2, as the farmer, being the targeted user, has the final say in whether or not a service is successful in changing farming decisions.

Table 7: Successful services and attributed factors

QCA	Factors explaining success	Success in words	Associated service(s)
Farmers	Age{1,2} & Medium{0,4}	Users older than 30 years, using a service on tv or by personal contact	Mati o Manush, DAE emergency info, DAE agri advisories
Developers	Medium{0,1,3-max}	Services not disseminated via print media	All except Agromet bulletin
Combined	Medium{0,4} & User feedback{1}	Services disseminated on tv or by personal contact, including a feedback system	Mati o Manush, DAE emergency info, DAE agri advisories

After conversion of the contents of Appendices D.1, D.2 and D.3, the input was loaded into the QCA tool Tosmana (version 1.5.4.0). This tool was then set to the options 'Explain Outcome 1', 'Exclude Outcome 0', 'Exclude Contradictions' and 'Include Remainders for Reduction". These options ensure the algorithm attempts to attribute success (outcome 1) to a simplified combination of underlying factors (the reduction of remainders). Considering there are three

options relating to handling contradictions, changing from 'Exclude Contradictions' to 'Include Contradictions for Reduction' or even to 'Explain Contradictions' did not affect the results for any of the three QCAs. Results explaining success can be retrieved from Table 7.

4.4 Actionability

This subsection attempts to give an insight in which types of information are actionable for farmers, supported by interview results and my own observations. Whereas the success definition of a service was dependent on three requirements (see section 3.3), in the QCA only the decision-making requirement (also labelled *action*) has been used. Therefore this subsection and the next one, 4.5, focus on the two other requirements: actionability and access, respectively. This subsection is, like subsection 4.3 above, expected to contribute towards answering sub question 2.

This subsection builds on the same 'type of data' classification as presented earlier on in the QCA, i.e. identified information types are agricultural, weather-related, market-related or linked to emergencies. An underlying assumption is that the actionability of each type of information is dichotomous. Results, more elaborately described in the remainder of this subsection, indicate weather-information is not actionable for farmers, while the other three types are.

To set off, two all-round criteria for achieving actionability will be mentioned. Firstly, the information should be provided in Bengali rather than English or other languages and secondly not in a written form when the user is illiterate (interviews 26 &27). These two criteria are valid independent of to which information type they refer.

Agricultural advisories in general are aimed at providing information for several activities that take place during agricultural activities, e.g. fertilizer application, seed handling and irrigation techniques. A senior farmer reported that this type of information is useful for farmers as the extension workers are well-educated (interview 23). According to him, the officers often studied agricultural science, have a practical approach and are experienced after visiting different places across Bangladesh. He also claimed farmers are able to understand DAE advisories very well, and that he provides their officers with feedback frequently. There are some occasions for that, one of them being during a publicly-accessible seminar organised at least ten times per year in the local primary school of which he was the principal. A Batiaghata DAE officer also confirmed that farmers can understand their advisories, and base crop, fungicide, pesticide, fertilizer and other decisions on it (interview 14). Agricultural information can therefore be considered actionable to farmers.

Weather information from BMD forecasts, Agromet bulletin, or other sources is frequently hard to interpret for farmers. In this thesis, eleven farmers (non-users) were approached in interviews about the BMD weather app and the Agromet bulletin, and one farmer (a user) about the AccuWeather application. None of these twelve changed agricultural decisions based on the presented information, signifying difficulties in interpreting weather data (interviews 26 &27). The only utilization of weather information in this thesis was found by the farmer using the AccuWeather applicatizon, which he used for a confirmation of own observations of the weather rather than for agricultural purposes (interview 21). Even this farmer mentioned he had some problems understanding some features like signing, symbols and the rating and feedback system. He additionally indicated it would be hard for farmers to realize what it means for them when the temperature in the application says 38 degrees (interview 21).

According to Mr. Alam, a BMD assistant director, farmers do have some kind of climatological understanding in their own way (interview 3). He also mentioned a translation to an advisory is required, without which disseminating weather information has a minimal effect (interview 3). This was confirmed by Batiaghata farmers who stated: ''The rain information can be useful for us, but at this point we are not exactly sure how. We can improvise to make this work, and maybe we can harvest early if we know rain is coming soon" (interview 26). Two important observations can be derived from this quote. Firstly, the farmers want to improvise in anticipation of the rain, as they have no experience in translating the forecast into an on-farm decision, in this case to safeguard their yield by harvesting early. Secondly the word 'know' as in 'we know that rain is coming' could imply that the farmers expect the prediction to be correct in all cases. In reality, rain can indeed be predicted but there is per definition a statistical uncertainty involved in forecasting, which the farmers seem not to be aware of.

Rainfall has, by Mr. Alam, been appointed as the most interesting weather parameter for farmers, although for other purposes than the farmers mentioned. According to him, in periods of rain farmers are keen on preventing high irrigation costs and additionally preventing seeds to rot during sowing works (interview 3). Possibly relating to the clear observability of rain, the rainfall parameter has practical value to farmers, but they do not as of yet realize its full potential for their risk management. Additional weather parameters like temperature or humidity may be even more difficult for farmers to interpret. Another Batiaghata farmer reported, after being presented with the Agromet bulletin: ''I think I understand the information well, all of it. I can use it too. Still, I cannot think of any crop that would change on the basis of this information" (interview 13). This is in line with earlier identified problems in translating weather information to farming decisions, making weather information not actionable.

Information about market prices of food or farming inputs is, for example available, via the dkrisi application and on the local markets (called bazaar). Another Batiaghata farmer reported that he, after a bazaar visit, triangulates market prices by making phone calls to peer farmers (interview 22). Claiming to be dependent on rice sales for his livelihood security, he uses pricing information to sell his produce after a price surge, or changes to cultivating more profitable gourd varieties. The dkrisi developer stated that he intended to make farmers less dependent on intermediaries by providing publicly-accessible market information (interview 5). This information is actionable for farmers, and could assist them in bargaining about prices of yield and agricultural inputs.

The last type of information, related to emergencies, has also been considered actionable for farmers. Considering dissemination of his information by DAE officers, a local farmer stated: ''I get information about which measures I should take, and how to protect my crops [..] I may cultivate my crops earlier than I did the previous year to escape from a flooding problem or other disasters." (interview 25). He recommended that the DAE officer would come more frequently than three times per month to visit their village for this and other information. The extension officers are not responsible for dissemination of such information via mass media, but operate by field and village visits similar to those for spreading agricultural information. The chief of the Batiaghata DAE office claimed the information to be ''very effective" (interview 9).

4.5 Opportunities and challenges

This subsection will focus on opportunities and challenges related to information services. It firstly describes which opportunities farmers have to access such services, both technological and human resource-based. After that, it addresses challenges for a forthcoming generation of information services. This subsection is expected to contribute towards answering sub question 3.

Opportunities
Being ''so far from technology" (interview 5), for many farmers DAE officers are the main source of information (interview 23). Farmers can go to DAE field meetings or send a household representative without being dependent on technological affairs beyond their control, a major advantage of traditional extension work. Although the DAE has a large-scale national network, their funding and manpower is limited (interview 14). A DAE officer reported he had been appointed 2345 farmers (out of the 30.000 in Batiaghata) to deliver on-field information to, with the number of farmers increasing slightly each year (interview 14). These numbers give reason to believe farmer households will not be visited too frequently. Apart from field visits, DAE officers can hence also be called via regular phone lines for information, a possibility used by farmers e.g. in case of high need. At least 80% of Bengali households is in possession of a normal mobile phone (Khatun *et al.*, 2014).

Farmers in peri-urban Khulna sometimes lack access to an internet connection. Although there is a mobile data network, out of the in total 82 approached farmers, only eight indicated to have access to such a network (interviews 15, 17, 21 & 26). The remaining farmers either indicated not to have access since they do not possess a smartphone, or have not been asked to answer internet-related questions as (1) their interview was about another service, or (2) they mentioned not to use any services at all. Smallholder farmers do not often possess mobile smartphones, for financial motives or because they consider paying for an internet connection otiose: ''Smartphones are generally not affordable for farmers. In addition, they would need an internet connection for which farmers often don't want to pay", a Batiaghata farmer said (interview 21). Considering many smallholder farmers generate low wages, a (smart)phone may be a substantial investment. Although the number of phone users in Bangladesh is slowly growing and reported to be around 85 million in 2017 (equating to 51% of the total population), only half of those are smartphones (GSMA, 2018). No research has been conducted as to how many of those are nationwide possessed by farmers, but it lies within the line of expectation that the majority of them will be used by inhabitants of the more developed, urbanised areas. The CEO of the BIID, developer of the several smartphone applications, stated the following: ''We notice that especially the young farmers are interested in receiving extension information [..] we are targeting the young people so that they can adopt new technologies."(interview 2). Young farmers have been shown to benefit from smartphone services, like a female Batiaghata farmer who stated ''I got a higher yield, and I noticed my crops are stronger, especially the paddy and the guava tree", after using a mobile application with crop disease information (interview 15). A young farmer who regularly watched agricultural videos on Youtube said: ''I decided to grow paddy twice a year instead of once" (interview 17). These two services could not have been incorporated into the QCA as their developers did not respond to interview requests.

The electric power supply is volatile and often absent. Reasons for cutting power include overloading of the network and prevention of short-circuiting damage during lightning storms or heavy rain. Remote areas frequently experience power cuts which may easily last several hours or up to half a day. This poses severe limitations to continuous reliance on electronic devices

and related assets, such as television, transistor radios, or mobile wireless connectivity. A female farmer in Batiaghata reported ''Often I have mobile data, but often there is no network connection so I cannot view websites. The network coverage is weak'' (interview 15). Even when power is available, in some locations the only accessible tv channel is government-operated BTV, as this channel constructed many network towers for large accessibility; satellite connections and antennas make it available anywhere in the country (interview 24).

Yet, access to electric power is only one asset, which does not explain the differences between television and radio usage. Rahman & Rahman (2012) report that no decent study on radio in Bangladesh has been conducted, but also state that most programmes are aimed at entertainment or promotion of the music industry rather than agriculture. In Batiaghata, a senior farmer stated ''Radio is almost extinct from this area, while television has developed" (interview 23). A possible reason for this phenomenon can be found when examining the opportunities farmers have to access tv or radio. Tea stalls in rural areas are found to be fulfilling a rather social function, allowing farmers to spend leisure time after work and gossip with peers. Often such stalls are equipped with a television, as audio-visual entertainment may attract customers (e.g. during the FIFA World Cup 2018, tea stalls were often completely packed with locals). ''I also know many other farmers in the village do not have a television", a Dumuria farmer claimed (interview 19), explaining why farmers do not often watch tv in a domestic environment. The social function of tea stalls make them more enticing places to spend leisure time, in its turn enabling access to tv for a larger audience. A disadvantage is that tea stalls are mainly aimed at providing entertainment to farmers during leisure time, not at broadcasting agricultural programs.

In summary, there are currently some established opportunities for farmers to retrieve information via television or agricultural extension. Novel opportunities for farmers include smartphone functionality, such as applications and webpages.

Challenges
Weather forecasts are not actionable pieces of information for farmers, and attuning agricultural decision-making is not a common practice (interviews 26 &27). A major unexplored challenge is hence the notion of how to service developers intend to increase actionability while designing meteorological forecast services.

In many services, there was no clear distinction as to which farmers were being targeted (interviews 3, 5, 6, 8, 9, 13 & 14), possibly in an effort to maximise the target group size. Another reason is simply because these services do not aim to function specifically for certain crops or user subgroups. However, farmers of different age, gender and educational background may have different social positions within a farming community, as well as different information needs and capacities. Absence of targeting specific farmers could be regarded as an indicator that tailored information services are yet to be designed as user characteristics have not been addressed. A possible implication is developers' lack of applied knowledge about user needs and capacities and the notion of how to those can assist in improving use of a service.

Another challenge is the notion of adding feedback mechanisms to existing services. The analysis revealed that services with user feedback were *always* more successful than those without it. However, adding such elements might increase the cost of design, maintaining or updating of a service, funds that a developer has to allocate. In addition, many services (e.g. AIS radio shows) are run using a classical top-down approach, where disseminated information is provided

by the developer or an intermediary instead of originating from field or user level (interviews 3, 4, 6, 9 & 14). Thus, incorporating an effective mechanism of user feedback would in many cases change the flow of information and stimulate developer-user interaction. For top-down services this means a radical change in design and operation of the platform, and additionally funds need to be allocated again. Increased cost and changes to the operational state of a service can thus be considered potential barriers to incorporation of user feedback.

5 Discussion

This discussion is divided into three parts. Firstly, the used conceptual framing will be subject of discussion, followed by the methodology. The last part of this chapter describes a discussion of the obtained results, placing it in a broader scientific context.

5.1 Discussion of conceptual approach

The concept used in this thesis, the end-to-end concept, turned out to be well-applicable for the case of information services in Bangladesh. Its main strength is the assembly of user and service-related aspects, in an effort to overcome commonly observed implementation problems. Nonetheless, the concept as retrieved from Goddard *et al.* (2001) was formulated broader than required to pursue the objectives of this thesis. Therefore its aspects related to climatic modelling have not been addressed in this study. An additional adjustment has been made for compliance with the pursued research objectives. Namely, this concept can also be applied for information types without predictive characteristics, or information not derived from modelling products. These two alterations have been made without compromising essential elements of the concept: interaction and feedback between user and service-related components.

For future reviews of existing information services, this concept can be used as underlying guideline, like in this thesis. Additionally, this thesis showed that with elimination of the topmost two elements of the concept, it still allows for service reviews, whereas the original full concept is aimed at designing new ones. Perhaps future researchers can keep this idea in mind, and apply it by eliminating those elements of the concept that are not required to pursue their objectives, and to keep relevant elements addressed. One condition is that potential eliminations have to start from the topmost or the bottommost element and consequently work their way down or up, respectively, so that the concept is not chopped into two separate parts.

5.2 Discussion of methodology

The mvQCA

This part of the discussion is about the usage of mvQCA as a tool. The mvQCA, like other QCA types, aims to support conclusions by deductive data set inference (Ragin, 1987). The main strength of this tool is that causality of an outcome is attributed to combinations of multi-valued predictors and cases (Haesebrouck, 2016). One limitation of this tool will be discussed here, related to the relative importance of addressed factors.

The mvQCA tool regards all factors to be of equal importance in attributing causality of a particular dichotomous outcome. Each causal predictor in the analysis has its own column, where corresponding values can be filled it for each case. These values are not ordinal or relative, but merely indicate the range of possibilities associated with each predictor – one value per possibility, starting from zero. A value in a certain column is thus of the same dichotomous weight as a value in any other column except outcome – either influential or not. Especially with applications in social science, it could instead be meaningful to make a distinction between factors with little weight and more powerful ones (cf. the fuzzy-set QCA or fsQCA (Ragin, 1987)). It is not inconceivable that a factor in some cases only has a little influence on causality of the associated outcome while mvQCA results indicate a full dependency or none whatsoever.

In the case of this thesis, the tool has been used with good understanding of the context and background of the research topic (see section 1.2), advisable for any mvQCA research. In an effort to detect such occurrences, it could be useful to increase the amount of cases for a more complete overview of which factors are influential under what conditions. Additionally, the occurrence of contradictory cases (cases with exactly the same values except the outcome) can be an indicator for variation in importance of factors.

Interviewing
During field work, it became clear that for some services the current number of users is very limited and consequentially (ex-)users were not easy to locate in the villages in Batiaghata and Dumuria. At a certain point during the interview sessions, 71 farmers had already been approached, of which 11 were interviewed as users and 60 were not interviewed as they are non-users. Of these 11, only three services (Mati o Manush and both DAE) were selected for the QCA. The other eight were not suitable (e.g. too many of them focus on television programs) or their developer did not respond to interview requests in time or not at all. Still, to complete QCA input tables, interviews with farmers had to be conducted one way or another. As last resort, it was decided for the remaining five QCA services to interview non-users instead. To balance the amounts of users and non-users, also 11 non-users have been interviewed (in two group sessions, interview 26 & 27). The total amount of approached farmers hence comes to 82, of which 22 have been interviewed. The originally intended methodology was to interview farmers who use services (to find success) and those who abolished them (to find failure). This plan has not been executed as intended, since not enough users (and ex-users) could be located.

Upon initial exposure of services to non-users, farmers do not have experience with the service yet – implying their response to it could be different than after recognising the features of a service more thoroughly. Results of this thesis would presumably have been of higher consistency if for each service a current or ex-user would have been interviewed. It can therefore even be debated whether or not the fact that only for the three successful farmer QCA services a current user has been interviewed played a role. Looking in hindsight, it is difficult to establish meaningful insights as to this. Perhaps the biggest weak point in this thesis is this ambiguity.

Another consequential limitation of little use is that not sufficient attention has been paid to interview a representative user group in terms of age, gender or other characteristics – the primary priority was to locate users at all. As most farmers turned out to be non-users, representative interviewing was easier among the latter group: both genders delivered input almost equally frequent, and all age groups (young, middle age and elderly) have been represented. This can be taken into consideration when discussing the results.

5.3 Summary and discussion of results

Available services
This thesis has initially observed which information services are offered to peri-urban Khulna farmers, The first conclusion is that a multitude of information is available for farmers, with many of those services operational on a national scale. Out of close to 200 identified services, a remarkable amount, four categories have been established.

1. Weather information consists of forecasted, current or historical data sets of predominantly rainfall and temperature, although other parameters like humidity and wind velocity are

also disseminated.

2. Emergency warnings include notices of heavy rainfall, squally wind, flooding, droughts and heat waves.
3. Agricultural advisory is a broad term and relates to information on agricultural activities: crop growth in various stages, accounting for seasonality, seeding, pesticide, fungicide and fertilizer application, plant disease remedies and irrigation techniques.
4. Market information relates to food or agricultural input pricing on local markets or other places.

The majority of services available in Khulna is available nationwide, including but not limited to governmental services and mobile applications. Irrespective of by which medium it is disseminated, weather information from Bangladesh is always developed and disseminated by BMD, although inhabitants of border regions are also able to receive weather information from the IMD or AccuWeather. Weather information is provided free of charge by the BMD and is disseminated to national mass media via the state-owned news agency Bangladesh Sangbad Sangstha (BSS).

Other services come in the shape of television programs, developed by government bodies on public television or available on many of the private tv channels. Most often, tv programs display agricultural information and weather forecasts. In case of approaching emergencies, warnings are also disseminated by the responsible government authority, using conventional mass media and a network of extension workers. And although radio listening declined heavily the past decades, there is still ample supply of agricultural radio shows. As of yet, extension work and television account for the highest information uptake by farmers in peri-urban Khulna.

A relative new phenomenon is the emergence of digital technology such as dissemination via smartphone applications and webpages. Although most farmers households are in possession of a mobile phone without 'smart' functionality, a rapid increase of the latter technique can be observed. A tremendous amount of applications is already available in application stores, often provided free of charge. Although these techniques are the latest addition in the technological spectrum, all four kinds of information can already be retrieved from them.

Compared to other studies, it can be concluded that other studies mostly present less detailed findings about information availability. For example, a brief comparison will be made with the results presented by Adomi *et al.* (2003) for the case of rural Nigeria and by Lwoga *et al.* (2011) for Tanzania. Both articles mention sources of information related to the personal environment of farmers, mass media, libraries, agricultural extension, etc. However, neither of them splits these sources into specific information services, therefore grouping services developed by governmental authorities, private providers, NGOs, or religious bodies together. This could possibly lead to overlooking valuable details, as providers often intend to effectuate different objectives using diverse methodologies. Presenting 'lumped information', with its origin still unknown, maintains keeping available information fragmentated. In Bangladesh, fragmentation plays a similar role, with previously no overview of water information services being available around Khulna (Kumar, 2017). Therefore this thesis made a valuable step by identifying services providers and intermediaries.

QCA results

Since it is likely there is some overlap in how available services have been designed or dissemi-

nated, it is not relevant to describe all nearly 200 services. Instead a selection of eight of them has been made, encompassing all identified media and information types. These eight have been scrutinized using a mvQCA, combining farmer and developer interviews as input.

QCA results indicate that user decision-making processes so far have only been impacted by combining user feedback with either tv programs or services with a personal approach. Although it is widely recognised that tv and agricultural extension are established ways of reaching farmers (Alam & Haque, 2014; Lwoga *et al.*, 2011; Adomi, 2003), no study as of yet claimed they only lead to adapted decision-making in combination with user feedback. Other observed information sources including radio shows and mobile phone applications turned out not to impact decision-making in the QCA. The majority of analysed factors, like presence of monitoring systems, informational costs and design strategies incorporating or neglecting user needs have also been found not to play a role. Where for example Qiang *et al.* (2016) emphasize the importance of a learning and monitoring culture where information guides decision-making, he stresses such culture is critical to assessing impacts of rural information services. Golding *et al.* (2017) describe that incorporating user requirements in the design of information services has not well enough been studied, and that the depth of user engagement (or lack thereof) can be decisive for the success of a climate service. Nonetheless QCA results indicate straightforwardly that the factors monitoring and design strategy are of no influence for decision-making whatsoever.

Although the QCA results are not in accordance with literature, that does not necessarily limit their validity. It is indeed possible that valid QCA output can contradict literary findings. After all, this output has been derived from the personal opinions of farmers and developers, complemented with independent observations. Additionally, the factors identified from literature have not a priori been assumed to be influential for the success of information services in peri-urban Khulna (see section 3.1). However, it is likely that in the analysis the amount of factors was too high in relation to the amount of observed cases. In other words, the algorithm has too many causal predictors to take into account, or too few services. This has most likely caused the exclusion of the majority of the factors from the results. No contradictions occurred in the input table, as explained in section 4.3. Since the majority of the factors does currently not play a role in the QCA results, it is not inconceivable that some of them might only be of a little influence while the mvQCA indicates no dependency whatsoever. This can in future research be resolved by increasing the amount of cases (which can be time-consuming as each case needs two interviews as input) or decreasing the amount of factors.

One advantage of usage of the mvQCA can perhaps be found in its methodological setup, apart from its obvious function to address causality. Completing the input tables, exactly the same factors will be addressed for each service, in the same manner for each factor. Taking the same assessment criteria for each service leads to a standardised data acquisition procedure. Truth tables allow for easy comparison and a quick overview of the properties of information services. For example, it is at a glance clear that only two of them have monitoring systems in place and most services have been designed using a top-down approach.

Actionability
Actionable knowledge has by Geertsema *et al.* (2016) been defined as knowledge that is (1) context-specific and (2) assisting decision-making of stakeholders. Observed non-actionable information for farmers turned out to be weather-related, with the three other types observed to be actionable. Developers considered all information types to be actionable. From the results and by Geertsema *et al.* (2016), it can be derived that the exact same piece of information

can be both actionable and not actionable at all, depending on to whom the information is presented. A good example is the actionability of weather information: while a BMD expert claims the farmers want to know rainfall information to prevent flooding, interviewed farmers do not know how to interpret this information into decisions (interviews 3 & 26). Such occurrences do not compromise the validity of the results, but is important to recognise from whose viewpoint information is considered actionable. In this thesis, interview results have been presented from two diverse groups. Attempts have been made to represent both groups in the results section. Nonetheless, the conclusions are always based on the farmers' viewpoint, as they are the ones who are expected to use the services for their decision-making.

Secondly, in the interviews there has not been a specific question dedicated to actionability. A reason to omit this phrasing is because the term itself has become a buzzword (Kerr, 2011) and mentioning it might therefore steer interviewees responses. Another reason is that interviewees, especially farmers, might not be familiar with the word actionable, or get lost in translation. Instead to assess actionability, interview responses to 'knowledge' and 'decision' questions have been analysed. Information was considered actionable when the interviewee could connect knowledge obtained from the services to a corresponding decision, irrespective of whether or not this decision had actually been taken already.

Opportunities
Farmers often do not possess ample ways of accessing information services. This thesis found farmers not always to possess a television or radio at home, or to have a stable internet connection. Mainly young farmers were found to have access to smartphones, whereas older farmers prefer traditional handheld phones. Because of among other these limitations on technological information transfer, DAE officers are among the main sources of information. Television is also popular, albeit watched from tea-stalls instead of at home.

While no decent study for radio in Bangladesh has been conducted (Rahman & Rahman, 2012), Hasan *et al.* (2017) claimed that most farmers around Khulna do not listen to agricultural radio. In a study about television, Alam & Haque (2014) report that BTV, the most preferred tv channel among their respondents, has coverage of 97% of the Bengali population. They identify Mati o Manush as the most interesting agricultural program and DAE as the second most popular information source. These literary findings are in accordance with the ones presented in this thesis. Information relevant for agriculturists would currently best be disseminated through either of these two media.

Interestingly, this thesis presents mixed results as to mobile technology. Although the three smartphone services incorporated in the QCA have been labelled as failure, smartphone services have shown significant potential outside of the QCA, directly based on interviews. A difference is that the interviewees of the smartphone services outside the QCA are relatively young: 21 and 28, while the QCA-included interviewees were families of mixed age. No additional differences have been identified. Still, it cannot be assessed if this age difference is of determinative importance, as no literature has been found on smartphone use by Bengali agriculturalists. However, when assessing smartphone use in general, these phones have been reported to be more integrated into the lives of younger people compared to the elderly (McGaughey *et al.*, 2013). This corresponds with the findings from the interviews.

Challenges
An identified challenge is the lack of weather information actionability. Traditional knowledge

possessed by farmers is in this regard not supplemented by scientific information from forecasting services. And although Roncoli *et al.* (2002) mention scientific information should be integrated with local knowledge for rural development, this clearly has not happened as of yet with weather information in Bangladesh. Similarly, constrains regarding user understanding and response capacity limit widespread use, a phenomenon described by Hansen *et al.* (2011) and Chowdhury (2005). This thesis confirms that these literary findings occur on a large scale among peri-urban Khulna farmers, and adds to these results by indicating more specifically under which conditions they are found to occur. Studies in other countries (e.g. ones in the US and Senegal) describe similar limitations as to farmers' use of forecast information (Roudier *et al.*, 2014; Hu *et al.*, 2006). It thus remains a challenge for farmers to understand and interpret weather forecasts for attuning their decision-making accordingly.

Developers seem quite optimistic: seven out of eight QCA services were considered influential for user decision-making, whereas in reality only three of them were. Developers mostly do not target farmer subgroups, include user feedback or their information needs. Perhaps this relates to more technical aspects of service design and delivery (Islam *et al.*, 2013; Paul & Routray, 2013), which are beyond the scope of this thesis. Still, it has already been recognised that (lack of) engagement with users could determine if a service will be successful (Golding *et al.* , 2017). Hence, developers need to be increasingly aware of the actual impacts their services makes. Moving them towards improvement of the service (e.g. through inclusion of user feedback) remains thus a challenge.

6 Conclusion

Agricultural information services operate by delivering information to agricultural users, from which they are expected to benefit. This thesis has attempted to identify what makes agricultural information services change farmer decision-making in peri-urban Khulna, Bangladesh, a region with an erratic water supply in a quickly developing and urbanising context. Several implementation problems have been observed in literature, related to shortcomings in farmers' access to services and limitations in understanding scientific information.

The conceptual frame in this thesis, the end-to-end concept by Goddard *et al.* (2001), depicted information services as sequential elements consisting of information, user knowledge, decisions and outcomes, respectively. These are connected by interactive and feedback processes; e.g. alterations made to one of them could have consequences for adjacent elements. Although originally intended as theoretical support for designing new services, this conceptual frame has in proven to be useful for reviewing existing ones.

Almost 200 information services potentially relevant for the agricultural sector have been identified as available in peri-urban Khulna. This thesis has found weather information, agricultural advisories, emergency warnings and market data to be disseminated in that region. Dissemination takes place via one or multiple conventional mass media, extension work or internet (via browsing, social media, and mobile applications). Eight information services, encompassing the identified media and information types, have been analysed using 27 qualitative interviews with both developers and users. These interviews serve as an input for a multi-value Qualitative Comparative Analysis (mvQCA).

mvQCA results indicate success can be explained by two conditions: (1) information should be disseminated via a personal approach or via tv, and (2) the services should include a user feedback system. Only extension services related to agriculture advisories and emergencies, and the agricultural television program Mati o Manush were considered successful in the QCA input. Other QCA data indicates developers tend to overestimate the impacts of their service by assuming farmers incorporate it into their decision-making. Developers design their services mostly top-down, do not target farmer subgroups and mostly do not have monitoring or feedback systems in place. On the other hand, farmers are more sceptical about using services: they frequently lack access to (digital) technology, tend to rely on traditional knowledge, and have no experience translating weather forecasts into farming decisions. Data indicate they seldom are given opportunities to provide feedback and, although information is provided free of charge, they have to pay for network or electricity costs. Additionally, young farmers can derive benefits from smartphone functionality more easily than their older colleagues.

Despite some limitations related to the execution of the mvQCA, the results are indicative for the modus operandi of agricultural information services in peri-urban Khulna. This thesis will be concluded with the statement that farmers could grab much more opportunities than they do now by heeding to available technology, and developers could increase the impacts of their services by implementing a user feedback mechanism.

Recommendations for future research
For future research using a mvQCA it is advised to have a good understanding of the case background before attempting to determine which causal predictors and cases should be included in the analysis. Being critical on both input and output and using common sense are highly advised. As input can be conflicting, depending on the source and validity, it is important to integrate the data from different sources into one QCA that is complemented by independent observations. The role of the researcher in this is to bridge potential gaps in perceptions on information use by collecting data from various sources.

Future research could include a more broader farmer group, balancing interviewees for example in terms of age, gender or education. Another option is to take a different focus by addressing farmer households rather than individual farmers. This will make it easier to address gender gaps and problems related to the social status of a farmer within his or her community.

In the future, research could attempt to unveil what the possibilities are to incorporate user feedback into existing or new services, and what that implies for the impact of those services. As a first step it has to be researched what types of feedback users are able and would like to provide under which circumstances.

Future studies could also address which steps are required to make weather information actionable for farmers. Given the relevance of weather information for farmers who face an erratic water supply or other pressures, it could be of benefit to them. Keeping in mind weather information does not have to replace indigenous climatic knowledge, a related research could be aimed at integrating scientific and traditional knowledge.

Lastly, future research could be aimed at agricultural information services in different regions than Khulna or on a national level. Research activities for this thesis specifically focused on peri-urban Khulna, an urbanising coastal region with around 30.000 farmers. Taking into account the large climatic variations across the ecological zones of Bangladesh (coastal versus inland, variations in soil types, variations in flood vulnerability in lower or higher regions, presence of mangrove, hills or rivers, etc.), it is likely that farmers' agricultural practices across the country will deviate from the ones common around Khulna. Although within this thesis no research has been conducted about socioeconomic conditions in different regions of Bangladesh, it is assumed these conditions vary across climatic zones due to differences in productivity and cultivated crop types. It is also assumed that across the coastal zone (Khulna, Barisal, Pathuakali, excluding the eastern coast near Chittagong) agricultural practices will be of similar nature due to the same salt-intruded environment and comparable climatic typology. Future research could use the findings of this thesis to review information services available in the rest of Bangladesh, or use this thesis to design or improve existing ones across the country.

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Appendices

Appendix A: List of services accessible in Khulna district

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
1	2	ABP News	Private Indian tv	Weather forecast	Tv, internet
2	4	AccuWeather Inc.	Private company	Weather forecast	Internet, mobile app
3	5	ACI Agribusiness Ltd.	Private company	Intelligent Decision Support System (IDDS)	Mobile app
4	6	Agriculture Information Service (AIS)*	Gov't of Bangladesh	Agricultural Affairs-Krishi Samachar	Radio
4	7	Agriculture Information Service	Gov't of Bangladesh	Cultivation-Chashabad	Radio
4	8	Agriculture Information Service	Gov't of Bangladesh	My country my soil-Desh Amar Mati Amar	Radio
4	9	Agriculture Information Service	Gov't of Bangladesh	Green field-Shobuj Prantor	Radio
4	10	Agriculture Information Service	Gov't of Bangladesh	Green Crop-Shoshho Shaymol	Radio
4	11	Agriculture Information Service	Gov't of Bangladesh	My country-Amar Desh	Radio
4	13	Agriculture Information Service	Gov't of Bangladesh	Agricultural Speaker-Krishi Kothka	Print media, mobile app
4	15	Agriculture Information Service	Gov't of Bangladesh	Agricultural advisories	Internet, mobile app
4	16	Agriculture Information Service	Gov't of Bangladesh	Krishi Call Centre	Phone call
4	17	Agriculture Information Service	Gov't of Bangladesh	Agro Knowledge Bank	Mobile app
4	18	Agriculture Information Service	Gov't of Bangladesh	Geopotato	SMS
5	20	Agromet	Gov't of India	Agricultural Philosophy-Krishi Darshan	Tv, internet
6	22	Alien Apps Factory	Private company	Agricultural Information-Krishi Tathya	Mobile app
7	22	All India Radio (AIR) Kolkata	Public Indian radio	IMD Agricultural advisories	Radio
8	23	All India Radio Kurseong	Public Indian radio	IMD Agricultural advisories	Radio
9	24	All India Radio Murshidabad	Public Indian radio	Farmer's Voice-Kisanvani	Radio
9	25	All India Radio Murshidabad	Public Indian radio	IMD Agricultural advisories	Radio
10	26	All India Radio Santiniketan	Public Indian radio	Farmer's Voice-Kisanvani	Radio
10	27	All India Radio Santiniketan	Public Indian radio	IMD Agricultural advisories	Radio
11	28	All India Radio Siliguri	Public Indian radio	IMD Agricultural advisories	Radio
12	30	Alterra	Wageningen University	GEOBIS	Mobile app, phone call, etc.

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
13	35	American Red Cross		CSRD bundle (PANI, weather forecast, wheat blast modelling, drought forecast & Stempedia)	Mobile app, etc.
14	35	Asian Development Bank	Private company	CSRD bundle	Mobile app, etc.
15	36	ATN-Bangla	Private Bengali tv	Agriculture Based Documentary-Krishi Bishoyok Pramanno Anushthan	Tv
15	37	ATN-Bangla	Private Bengali tv	Unending Bangla-Obiram Bangla	Tv
15	38	ATN-Bangla	Private Bengali tv	Weather forecast	Tv, internet
16	39	Awesome BD APP	Private company	Agricultural info-Krishi Tottho	Mobile app
17	40	Bangla Public Library		Aus paddy cultivation	Mobile app
17	41	Bangla Public Library		Barley cultivation	Mobile app
17	42	Bangla Public Library		Bati spinach cultivation	Mobile app
17	43	Bangla Public Library		Bean cultivation	Mobile app
17	44	Bangla Public Library		Betel leaf cultivation	Mobile app
17	45	Bangla Public Library		Calabash cultivation	Mobile app
17	46	Bangla Public Library		Corn cultivation	Mobile app
17	47	Bangla Public Library		Cotton cultivation	Mobile app
17	48	Bangla Public Library		Cowan cultivation	Mobile app
17	49	Bangla Public Library		Cowpea cultivation	Mobile app
17	50	Bangla Public Library		Chrysanthemum	Mobile app
17	51	Bangla Public Library		Dragon fruit cultivation	Mobile app
17	52	Bangla Public Library		Eggplant cultivation	Mobile app
17	53	Bangla Public Library		Garlic cultivation	Mobile app
17	54	Bangla Public Library		Ginger cultivation	Mobile app
17	55	Bangla Public Library		Groundnut cultivation	Mobile app
17	56	Bangla Public Library		Guava cultivation	Mobile app
17	57	Bangla Public Library		Jububе cultivation	Mobile app
17	58	Bangla Public Library		Jute cultivation	Mobile app
17	59	Bangla Public Library		Lemon cultivation	Mobile app
17	60	Bangla Public Library		Papaya cultivation	Mobile app
17	61	Bangla Public Library		Lettuce cultivation	Mobile app
17	62	Bangla Public Library		Linseed cultivation	Mobile app
17	63	Bangla Public Library		Lychee cultivation	Mobile app
17	64	Bangla Public Library		Mango cultivation	Mobile app

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
17	65	Bangla Public Library		Moringa oleifera cultivation	Mobile app
17	66	Bangla Public Library		Cabbage cultivation	Mobile app
17	67	Bangla Public Library		Mustard cultivation	Mobile app
17	68	Bangla Public Library		Okra cultivation	Mobile app
17	69	Bangla Public Library		Onion cultivation	Mobile app
17	70	Bangla Public Library		Orange cultivation	Mobile app
17	71	Bangla Public Library		Palm oil cultivation	Mobile app
17	72	Bangla Public Library		Pineapple cultivation	Mobile app
17	73	Bangla Public Library		Pointed gourd cultivation	Mobile app
17	74	Bangla Public Library		Potato cultivation	Mobile app
17	75	Bangla Public Library		Quick compost	Mobile app
17	76	Bangla Public Library		Radish cultivation	Mobile app
17	77	Bangla Public Library		Red spinach cultivation	Mobile app
17	78	Bangla Public Library		Sponge gourd cultivation	Mobile app
17	79	Bangla Public Library		Stevia cultivation	Mobile app
17	80	Bangla Public Library		Strawberry cultivation	Mobile app
17	81	Bangla Public Library		Sugarcane cultivation	Mobile app
17	82	Bangla Public Library		Sugarcane cultivation	Mobile app
17	83	Bangla Public Library		Bitter melon cultivation	Mobile app
17	84	Bangla Public Library		Banana cultivation	Mobile app
17	85	Bangla Public Library		Cauliflower cultivation	Mobile app
17	86	Bangla Public Library		Paddy cultivation	Mobile app
17	87	Bangla Public Library		Tea cultivation	Mobile app
17	88	Bangla Public Library		Til cultivation	Mobile app
17	89	Bangla Public Library		Tomato cultivation	Mobile app
17	90	Bangla Public Library		Tuberose cultivation	Mobile app
17	91	Bangla Public Library		Turnip cultivation	Mobile app
17	92	Bangla Public Library		Wheat cultivation	Mobile app
17	93	Bangla Public Library		Yellow spice cultivation	Mobile app
18	94	Bangla Vision	Private Bengali tv	Green Bangla-Shaymol Bangla	Tv
19	95	Bangladesh Agriculture Research Institute (BARI)	Gov't of Bangladesh	BARI application	Mobile app
19	97	Bangladesh Agriculture Research Institute	Gov't of Bangladesh	Agrotechnology Handbook	Internet, print media
20	98	Bangladesh Betar (BB) Dhaka	Public Bengali radio	Weather forecast	Radio

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
20	99	Bangladesh Betar Dhaka	Public Bengali radio	My Country My Soil-Desh Amar Mati Amar	Radio
20	100	Bangladesh Betar Dhaka	Public Bengali radio	Agricultural Affairs-Krishi Samachar	Radio
20	101	Bangladesh Betar Dhaka	Public Bengali radio	Green Field-Shobuj Prantor	Radio
20	102	Bangladesh Betar Dhaka	Public Bengali radio	Green Crop-Shoshho Shaymol	Radio
20	103	Bangladesh Betar Dhaka	Public Bengali radio	My Country-Amar Desh	Radio
21	104	Bangladesh Betar Khulna	Public Bengali radio	Weather forecast	Radio
21	105	Bangladesh Betar Khulna	Public Bengali radio	Agricultural Affairs-Krishi Samachar	Radio
21	106	Bangladesh Betar Khulna	Public Bengali radio	Cultivation-Chashabad	Radio
22	107	Bangladesh Centre for Advance Studies (BCAS)	NGO	WaterApps	Mobile app
22	107	Bangladesh Centre for Advance Studies	NGO	Geopotato	SMS
23	107	Bangladesh Institute for ICT Development (BIID)	Private company	PANI	Mobile app
23	108	Bangladesh Institute for ICT Development	Private company	e-Krishok	Mobile app
23	109	Bangladesh Institute for ICT Development	Private company	Farmbook Business planning tool	Mobile app
23	110	Bangladesh Institute for ICT Development	Private company	Zero Cost Extension & Advisory Service	Mobile app
23	111	Bangladesh Institute for ICT Development	Private company	Ground Cover App for Irrigation Scheduling	Mobile app
24	112	Bangladesh Meteorological Department (BMD)	Gov't of Bangladesh	BMD weather forecasts	Tv, radio, internet, newspaper
24	113	Bangladesh Meteorological Department	Gov't of Bangladesh	BMD Weather App	Mobile app
24	115	Bangladesh Meteorological Department	Gov't of Bangladesh	BMD Current Weather App	Internet, mobile app
24	117	Bangladesh Meteorological Department	Gov't of Bangladesh	Agromet bulletin	Internet, email
24	119	Bangladesh Meteorological Department	Gov't of Bangladesh	Aquaculture App	Internet, mobile app
25	120	Bangladesh Television (BTV)	Public Bengali tv	Agriculture of Bengal-Banglar Krishi	Tv
25	121	Bangladesh Television	Public Bengali tv	Agriculture News-Krishi Songbad	Tv
25	122	Bangladesh Television	Public Bengali tv	Agriculture Round the Clock-Krishi Dibanishi	Tv

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
25	123	Bangladesh Television	Public Bengali tv	Country and Population News-Desh O Jonopoder Khobor	Tv
25	124	Bangladesh Television	Public Bengali tv	Soil and Man-Mati o Manush	Tv
25	125	Bangladesh Television	Public Bengali tv	Unending Bangla-Obiram Bangla	Tv
25	126	Bangladesh Television	Public Bengali tv	Weather forecast	Tv
26	127	Bangladesh Water Development Board (BWDB)	Gov't of Bangladesh	Blue Gold	Personal contact
26	130	Bangladesh Water Development Board	Gov't of Bangladesh	Flood warnings (by FFWC)	Tv, radio, internet
27	131	Banglalink	Private company	Agricultural Inquiry 7676-Krishi Jigyasha 7676	Phone call
28	132	Bengal's Agriculture		Bengal's Agriculture	Youtube
29	132	BETS Consulting Services	Private company	Blue Gold	Personal contact
30	133	Boishakhi Television	Private Bengali tv	Agriculture and Life-Krishi o Jibon	Tv
30	134	Boishakhi Television	Private Bengali tv	Seven Colours of Success-Shat Rong	Tv
31	134	BRAC	NGO	Blue Gold	Personal contact
32	135	Caritas Bangladesh		Sustainable Food and Livelihood Security	
32	136	Caritas Bangladesh		Sustainable Food and Livelihood Security II	
33	136	Catholic Relief Services		Farmbook Business planning tool	Mobile app
33	136	Catholic Relief Services		Sustainable Food and Livelihood Security	
33	136	Catholic Relief Services		Sustainable Food and Livelihood Security II	
34	137	Center for Hydrometeorology & Remote Sensing (CHRS)	University of California Irvine	iRAIN UCI	Mobile app
35	138	Channel-I	Private Bengali tv	Agricultural Budget-Krishi Budget	Tv
35	139	Channel-I	Private Bengali tv	Agricultural News-Krishi Bartha	Tv
35	140	Channel-I	Private Bengali tv	Agricultural News-Krishi Songbad	Tv
35	141	Channel-I	Private Bengali tv	Agriculture Round the Clock-Krishi Dibanishi	Tv
35	143	Channel-I	Private Bengali tv	Soil and Man in the Heart-Hridoye Mati o Manush	Tv, internet
35	145	Channel-I	Private Bengali tv	Call of Soil and Man in the Heart-Hridoye Mati o Manusher Dak	Tv, internet

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
35	146	Channel-I	Private Bengali tv	Weather forecast	Tv
36	146	International Maize and Wheat Improvement Centre (CIMMYT)		CSRD bundle	Mobile app, etc.
36	146	International Maize and Wheat Improvement Centre		Ground Cover App for Irrigation Scheduling	Mobile app
37	148	DD Bangla	Public Indian tv	Agricultural Philosophy-Krishi Darshan	Tv, internet
38	148	Delta Alliance Bangladesh Wing		DeltaCAP	
39	149	Department of Agricultural Extension (DAE)*	Gov't of Bangladesh	Agricultural advisories	Personal contact
39	150	Department of Agricultural Extension*	Gov't of Bangladesh	Emergency weather advisories	Personal contact
39	151	Department of Agricultural Extension*	Gov't of Bangladesh	Agromet bulletin	Personal contact
39	151	Department of Agricultural Extension*	Gov't of Bangladesh	IDDS	Mobile app
39	152	Department of Agricultural Extension*	Gov't of Bangladesh	Blue Gold	Personal contact
39	153	Department of Agricultural Extension*	Gov't of Bangladesh	Farmer's Window-Krishoker Janala	Mobile app
39	154	Department of Agricultural Extension*	Gov't of Bangladesh	Farmer's Digital Address-Krishoker Digital Thikana	Mobile app
39	155	Department of Agricultural Extension*	Gov't of Bangladesh	Pesticide Prescriber	Mobile app
40	155	Department of Fisheries	Gov't of Bangladesh	Blue Gold	Personal contact
41	155	Department of Livestock Services	Gov't of Bangladesh	Blue Gold	Personal contact
42	156	Desi Kheti		Desi Kheti	Youtube
43	157	Disaster Management Bureau (DMB)	Gov't of Bangladesh	Emergency warnings	Personal contact
44	157	Division of Agricultural Meteorology	Gov't of India	Agricultural Philosophy-Krishi Darshan	Tv, internet
45	157	Doordarshan (DD)	Public Indian tv	Agricultural Philosophy-Krishi Darshan	Tv, internet
45	158	Doordarshan (DD)	Public Indian tv	Weather forecast	Tv
46	159	Edu Apps Bd		Land Calculator-Bhumi Porimap Nirnoy	Mobile app

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
47	161	Electrosys ICT Ltd.	Private company	d-agriculture-dkrisi	Internet, mobile app
48	161	Environmental Science (ES) Discipline	University of Khulna	WaterApps	Mobile app
49	162	Esri		CSRD bundle	Mobile app, etc.
50	162	Faculty of Geo-Information Science and Earth Observation	University of Twente	Ground Cover App for Irrigation Scheduling	Mobile app
51	162	FAO Bangladesh	Unided Nations	Blue Gold	Personal contact
52	163	Farm and farmers story		Farm and farmers story	Youtube
53	164	Farmer's friend TV		Farmer's friend TV	Youtube
54	165	Farming-Krishikagoj		Farming-Krishikagoj	Internet, mobile app
55	165	FemConsult		Blue Gold	Personal contact
56	165	Flood Forecasting and Warning Centre (FFWC)	Gov't of Bangladesh	Flood warnings	Tv, radio, internet
56	165	Geodata for Agriculture and Water (G4AW)	Gov't of the Netherlands	Geopotato	SMS
57	165	Geodata for Agriculture and Water	Gov't of the Netherlands	GEOBIS	Mobile app, phone call, etc
57	165	Geodata for Agriculture and Water	Gov't of the Netherlands	IDDS	Phone call, mobile app
58	165	Google	Private company	CSRD bundle	Mobile app, etc.
59	166	Grameenphone	Private company	Agricultural service-Krishi Sheba	Phone call
60	167	GTV	Private Bengali tv	Green Bangla-Shobuj Bangla	Tv
61	167	Hoogheemraadschap Hollands Noorderkwartier	Gov't of the Netherlands	WaterApps	Mobile app
62	167	ICCO-Cooperation		Geopotato	SMS
63	169	Indian Meteorological Department (IMD)	Gov't of India	Weather forecast	Tv, radio, internet
64	169	Inter-American Development Bank	Private company	CSRD bundle	Mobile app, etc.
65	169	Interdisciplinary Centre for Food Security (ICF)	Bangladesh Agricultural University	GEOBIS	Mobile app, phone call, etc.
66	170	KBC Bangla		KBC Bangla	Youtube
67	171	Agricultural Education-Krishi Shikkha		Agricultural Education-Krishi Shikkha	Youtube

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
68	172	Agricultural Enthusiast-Krishi Uddokta		Agricultural Enthusiast-Krishi Uddokta	Youtube
69	172	Lal Teer Seed Ltd.	Private company	GEOBIS	Mobile app, phone call, etc.
70	172	Max Foundation		Blue Gold	Personal contact
71	173	Md. Bayezid Moral		Md. Bayezid Moral	Youtube
72	173	MDF West Africa		WaterApps	Mobile app
73	173	Met Office		CSRD bundle	Mobile app, etc.
74	173	Ministry of Agriculture	Gov't of Bangladesh	All services under DAE and AIS	Tv, radio, internet
75	173	Ministry of Information	Gov't of Bangladesh	All services under Bangladesh Betar and BTV	Tv, radio, internet
76	173	Ministry of Earth Sciences	Gov't of India	All services under IMD	Tv, radio, internet
77	173	Ministry of Information and Broadcasting	Gov't of India	All services under Doordarshan	Tv, radio, internet
78	173	Ministry of Agriculture	Gov't of India	Agricultural Philosophy-Krishi Darshan	Tv, internet
79	173	Mott MacDonald	Private company	Blue Gold	Personal contact
79	173	m-Power	Private company	Geopotato	SMS
80	174	m-Power	Private company	Proshar App	Mobile app
80	175	m-Power	Private company	Agricultural Extension Support Activity (AESA)	Mobile app
80	175	m-Power	Private company	GEOBIS	Mobile app, phone call, etc.
81	175	Multisourcing Ltd.	Private company	GEOBIS	Mobile app, phone call, etc.
82	176	Muttaqin Muhamad		Muttaqin Muhamad	Youtube
82	177	National Apps Bangladesh		Rice Knowledge Bank	Mobile app
83	178	National Apps Bangladesh		Agriculture Info Service	Mobile app
83	179	National Apps Bangladesh		Insect Control Of Crop	Mobile app
83	180	National Apps Bangladesh		Production of cash crops-Orthokori Fasal Utpadon	Mobile app
84	180	Nelen en Schuurmans	Private company	IDDS	Mobile app
85	181	Netherlands Embassy in Dhaka	Gov't of the Netherlands	Blue Gold	Personal contact
86	181	Netherlands Geomatics & Earth Observation B.V./NEO	Private company	GEOBIS	Mobile app, phone call, etc.
86	181	Netherlands Space Office	Gov't of the Netherlands	Geopotato	SMS

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
87	181	Netherlands Space Office	Gov't of the Netherlands	GEOBIS	Mobile app, phone call, etc
87	181	Netherlands Space Office	Gov't of the Netherlands	IDDS	Phone call, mobile app
88	182	New Age	Private Bengali newspaper	Weather forecast	Newspaper
89	183	News Floor		News Floor	Youtube
90	183	NWO	Gov't of the Netherlands	WaterApps	Mobile app
91	184	Online tutorial 232		Online tutorial 232	Youtube
92	185	Practical Action		Krishi Call Centre	Phone call
93	185	Rabobank	Private company	WaterApps	Mobile app
94	186	Rajibul Islam		Rajibul Islam	Youtube
94	186	Robi Axiata Ltd.		Agricultural Message-Krishi Bartha	Phone call
95	187	Robi Axiata Ltd.	Agricultural Radio-Krishi Radio	Phone call	
96	188	Roza Agro Farm		Roza Agro Farm	Youtube
97	190	Salinity Research Center Batiaghata	Gov't of Bangladesh	Salinity Information System	Internet, mobile app
98	191	Samakal	Private Bengali newspaper	Weather forecast	Newspaper
99	191	SarVision		IDDS	Mobile app
100	191	Skoll global threats fund		CSRD bundle	Mobile app, etc.
101	191	Skymet Weather Services	Private company	Weather forecast	Tv, internet
102	192	SmartDevX		Land Measure-Bhumi Parimapa	Mobile app
103	192	SNV Netherlands		IDDS	Mobile app
104	192	SocioConsult	Private company	Blue Gold	Personal contact
105	192	Somoy News	Private Bengali tv	Weather forecast	Tv, internet
106	193	Tata Consultancy Services	Private company	mAgriculture-mKrishi	Mobile app
107	193	TerraSphere		Geopotato	SMS
108	194	The Daily Star	Private Bengali newspaper	Weather forecast	Newspaper
109	197	Today's Agriculture-Ajkerkrishi		Today's Agriculture-Ajkerkrishi	Internet, mobile app
110	197	UKAID	Gov't of the United Kingdom	CSRD bundle	Mobile app, etc.

Dev. count	Services count	Developer, provider or intermediary	Affiliation	Service name(s)	Dissemination media
111	197	UNESCO – IHE		DeltaCAP	
112	197	UNICEF Bangladesh		Blue Gold	Personal contact
113	197	USAID	Gov't of the USA	CSRD bundle	Mobile app, etc.
114	197	Wageningen Environmental Research	Wageningen University	DeltaCAP	
115	197	Water Systems & Global Change	Wageningen University	WaterApps	Mobile app
115	197	Water Systems & Global Change	Geopotato	SMS	
116	197	Waterschap Aa en Maas	Gov't of the Netherlands	WaterApps	Mobile app
117	197	WorldFish		Blue Gold	Personal contact
118	198	Zee News	Private Indian tv	Weather forecast	Tv

Note that some of the services in this table are still in development (e.g. WaterApps, CSRD, dkrisi). A * implies that all wings have been taken together as 1 developer, i.e. the national and all regional offices. Dissemination of the same information via multiple media has been counted as multiple services. This table attempts to count the amount of independent services. However in the case of the BMD/IMD, their forecasts are only counted when disseminated by themselves, otherwise it is counted as a service belonging to the associated media channel.

Appendix B: List of interviewees

B.1 Expert interviewees

Number	Date	Interviewee	Affiliation	Location	Language	Coll. with U. Kumar	Communication by
1	09-05-2018	C. Montes	CIMMYT	Dhaka	English	No	Personal interview
2	14-05-2018	S.U. Akbar	BIID	Dhaka	English	No	Personal interview
3	15-05-2018	S. Alam	BMD	Dhaka	English	No	Personal interview
4	15-05-2018	K. Parvin	BMD	Dhaka	English	No	Personal interview
5	16-05-2018	R. R. Islam	dkrisi	Dhaka	English	No	Skype interview
6	22-05-2018	M. M. Abdur Razzaque	AIS	Khulna	Bengali	Yes	Personal interview
7	23-06-2018	H. Ahsan	m-Power	Dhaka	English	No	Skype interview
8	23-06-2018	R. K. Siddique	BTV	Dhaka	English	No	Phone call interview
9	28-05-2018	R. Ara	DAE	Khulna	Bengali	Yes	Personal interview
10	30-05-2018	S. Mahmud	m-Power	Khulna	English	No	Personal interview
11	31-05-2018	A. Syed	BCAS	Khulna	English	No	Skype interview
12	04-06-2018	S. K. Malaker	Caritas	Khulna	Bengali	Yes	Skype interview
13	21-06-2018	M. M. Abdur Razzaque	AIS	Khulna	Bengali	No	Personal interview
14	24-06-2018	J. Roy	DAE	Khulna	Bengali	Yes	Personal interview

B.2 Farmer interviewees

Number	Date	Location	Language	Notes
15	03-05-2018	Jhorbhanga, Bathiaghata	Bengali	Current user
16	03-05-2018	Jhorbhanga, Bathiaghata	Bengali	Current user
17	25-05-2018	Kakmary, Dumuria	English	Current user; 8 illiterate farmers also present, not part of the interview
18	25-05-2018	Kakmary, Dumuria	Bengali	Current user; 7 illiterate farmers also present, not part of the interview
19	25-05-2018	Kakmary, Dumuria	Bengali	Current user; 7 illiterate farmers also present, not part of the interview
20	25-05-2018	Kakmary, Dumuria	Bengali	Current user; 9 illiterate farmers also present, not part of the interview
21	01-06-2018	Raingamari, Batiaghata	Bengali	Current user
22	01-06-2018	Raingamari, Batiaghata	Bengali	Current user
23	03-06-2018	Raingamari, Batiaghata	Bengali	Current user
24	03-06-2018	Raingamari, Batiaghata	Bengali	Current user
25	03-06-2018	Raingamari, Batiaghata	Bengali	Current user
26	23-06-2018	Raingamari, Batiaghata	Bengali	Non-users; Interview held with 5 respondents (5 of them illiterate)
27	23-06-2018	Raingamari, Batiaghata	Bengali	Non-users; Interview held with 6 respondents (4 of them illiterate)

Appendix C: List of information service factors

C.1 List of factors relevant for developers

#	Factor	Category	Literature source(s)
1	Gender	Target group	Rashid *et al.* (2016)
2	Age	Target group	Carayannis & Sagi (2000); Rashid *et al.* (2016); Rose *et al.* (2016)
3	Education	Target group	Carayannis & Sagi (2000); Rashid *et al.* (2016); Rose *et al.* (2016)
4	Farming experience	Target group	Rashid *et al.* (2016)
5	Farm size	Target group	Rashid *et al.* (2016); Rose *et al.* (2016)
6	Type of data	Design	Islam *et al.* (2013)
7	Transfer medium	Design	Islam *et al.* (2013)
8	Design strategy	Design	Golding *et al.* (2017); Hirschheim (1985); Thong (2001)
9	User feedback	Design	Chowdhury (2005)
10	Monitoring active users	Design	Qiang *et al.* (2009)
11	Monitoring info uptake	Design	Qiang *et al.* (2009)
12	Costs for user	Design	Rose *et al.* (2016)
13	Performance	Interaction	Rose *et al.* (2016)
14	Ease of use	Interaction	Rose *et al.* (2016)
15	Peer recommendation	Interaction	Rose *et al.* (2016)
16	Habit	Response	Rose *et al.* (2016)
17	Knowledge	Response	Goddard *et al.* (2001)
18	Decisions	Response	Goddard *et al.* (2001)
19	Outcomes	Response	Goddard *et al.* (2001)

C.2 List of factors relevant for farmers

#	Factor	Category	Literature source(s)
1	Gender	Target group	Rashid *et al.* (2016)
2	Age	Target group	Carayannis & Sagi (2000); Rashid *et al.* (2016); Rose *et al.* (2016)
3	Education	Target group	Carayannis & Sagi (2000); Rashid *et al.* (2016); Rose *et al.* (2016)
4	Farming experience	Target group	Rashid *et al.* (2016)
5	Land area	Target group	Rashid *et al.* (2016); Rose *et al.* (2016)
6	Type of data	Design	Islam *et al.* (2013)
7	Transfer medium	Design	Islam *et al.* (2013)
8	User feedback	Design	Chowdhury (2005)
9	Costs for user	Design	Rose *et al.* (2016)
10	Performance	Interaction	Rose *et al.* (2016)
11	Ease of use	Interaction	Rose *et al.* (2016)
12	Peer recommendation	Interaction	Rose *et al.* (2016)
17	Habit	Response	Rose *et al.* (2016)
18	Knowledge	Response	Goddard *et al.* (2001)
19	Decisions	Response	Goddard *et al.* (2001)
20	Outcomes	Response	Goddard *et al.* (2001)

Appendix D: QCA tables

D.1 QCA truth table resulting from developer interviews (in words and in numbers)

Service	Age targeting	Data type	Medium	Design strategy	User feedback	Cost for user	Monitoring active users	Monitoring information uptake	Success
e-Krishok	Young	Agri advice	Phone call	Collaborative	No	Free	Yes	Yes	Yes
Agromet bulletin	n.a.	Weather	Print media	Top-down	No	Free	No	No	No
BMD Weather app	Young	Weather	Mobile app	Top-down	No	Free	No	No	Yes
Krishi Samachar	n.a.	Agri advice	Radio	Top-down	No	Free	No	No	Yes
Mati o Manush	n.a.	Agri advice	Television	Collaborative	Yes	Free	No	No	Yes
DAE emergency info	n.a.	Emergency advice	Personal contact	Top-down	No	Free	No	No	Yes
DAE agri advisories	n.a.	Agri advice	Personal contact	Top-down	Yes	Free	Yes	Yes	Yes
dkrisi app	n.a.	Market prices	Mobile app	Bottom-up	No	Free	No	No	Yes

Service	Age targeting	Data type	Medium	Design strategy	User feedback	Cost for user	Monitoring active users	Monitoring information uptake	Success
e-Krishok	1	0	5	1	0	0	1	1	1
Agromet bulletin	0	1	2	0	0	0	0	0	0
BMD Weather app	1	1	3	0	0	0	0	0	1
Krishi Samachar & Chashabad	0	0	1	0	0	0	0	0	1
Mati o Manush	0	0	0	1	1	0	0	0	1
DAE emergency info	0	3	4	0	0	0	0	0	1
DAE agri advisories	0	0	4	0	1	0	1	1	1
dkrisi app	0	2	3	2	0	0	0	0	1

D.2 QCA truth table resulting from farmer interviews (in words and in numbers)

Service (Units where applicable)	Age (years)	Gender	Education (years)	Experience (years)	Farm size (decimals)	Data type	Medium	User feedback	Cost	Success
e-Krishok	20-29	Male	≤10	10-19	<200	Agri advice	Phone call	No	Low	No
Agromet bulletin	20-29	Male	≤10	10-19	<200	Weather	Print media	No	Low	No
BMD Weather app	20-29	Male	≤10	10-19	<200	Weather	Mobile app	No	Low	No
Krishi Samachar	20-29	Male	≤10	10-19	<200	Agri advice	Radio	No	Low	No
Mati o Manush	>40	Male	≤10	20-29	<200	Agri advice	Television	No	Low	Yes
DAE emergency info	30-39	Male	>11	10-19	201-399	Emergency advice	Personal contact	Yes	Free	Yes
DAE agri advisories	>40	Male	>11	30-39	≥400	Agri advice	Personal contact	Yes	Free	Yes
dkrisi app	20-29	Male	≤10	10-19	<200	Market prices	Mobile app	No	Low	No

Service (Units where applicable)	Age (years)	Gender	Education (years)	Experience (years)	Farm size (decimals)	Data type	Medium	User feedback	Cost	Success
e-Krishok	0	1	0	0	0	0	5	0	1	0
Agromet bulletin	0	1	0	0	0	1	2	0	1	0
BMD Weather app	0	1	0	0	0	1	3	0	1	0
Krishi Samachar & Chashabad	0	1	0	0	0	0	1	0	1	0
Mati o Manush	2	1	0	1	0	0	0	0	1	1
DAE emergency info	1	1	1	0	1	3	4	1	0	1
DAE agri advisories	2	1	1	2	2	0	4	1	0	1
dkrisi app	0	1	0	0	0	2	3	0	1	0

D.3 Combined QCA truth table (in words and in numbers)

Service	Age	Data type	Medium	Design strategy	User feedback	Cost	Monitoring active users	Monitoring information uptake	Success
e-Krishok	Young	Agri advice	Phone call	Collaborative	No	Low	Yes	Yes	No
Agromet bulletin	n.a.	Weather	Print media	Top-down	No	Low	No	No	No
BMD Weather app	Young	Weather	Mobile app	Top-down	No	Low	No	No	No
Krishi Samachar	n.a.	Agri advice	Radio	Top-down	No	Low	No	No	No
Mati o Manush	n.a.	Agri advice	Television	Collaborative	Yes	Low	No	No	Yes
DAE emergency info	n.a.	Emergency advice	Personal contact	Top-down	Yes	Free	No	No	Yes
DAE agri advisories	n.a.	Agri advice	Personal contact	Top-down	Yes	Free	Yes	Yes	Yes
dkrisi app	n.a.	Market prices	Mobile app	Bottom-up	No	Low	No	No	No

Service	Age	Data type	Medium	Design strategy	User feedback	Cost	Monitoring active users	Monitoring information uptake	Success
e-Krishok	1	0	5	1	0	1	1	1	0
Agromet bulletin	0	1	2	0	0	1	0	0	0
BMD Weather app	1	1	3	0	0	1	0	0	0
Krishi Samachar & Chashabad	0	0	1	0	0	1	0	0	0
Mati o Manush	0	0	0	1	1	1	0	0	1
DAE emergency info	0	3	4	0	1	0	0	0	1
DAE agri advisories	0	0	4	0	1	0	1	1	1
dkrisi app	0	2	3	2	0	1	0	0	0

E.1 Interview guide for farmers

Introduction

- Hello, I'm Vincent and I'm conducting agricultural research in this area.
- Several information services have been developed to support farmers' decisions. Information services provide information to you or other farmers, to help you practice agriculture.
- I'm are interested in your experience with this kind of information, so I'm are approaching local farmers for interviewing. Is it okay if I interview you?
- This interview takes about 20 to 25 minutes, and the results are saved anonymously.
- I will use a recorder to analyze the questions and listen back, is that all right with you?

Introduction questions

- Could you introduce yourself?
- What is your age?
- For how long have you been a farmer?
- How many years have you been in school?
- How big is your agricultural land?
- Which crop(s) are you growing now?

Research questions

- Which information services are known to you?
- Which information do you obtain from this service?
- Why do you find this type of information useful?
- For how long have you been using this service?
- Why do you consider the medium you use to get this information to be useful in transferring information to you?
- How much money do you have to pay to retrieve this information?
- Which knowledge from this service helps you to farm?
- Which of your farming decisions changed after getting information from service?
- Which changes did you observe regarding your land or crops after using the service?
- What do you think would be the best step to improve this service?
- Which kind of feedback do you provide to the service?
- How often do you do that?
- How would you rate the performance of this service?
- How easy is this service to use?
- Which role does peer recommendation play for using this service?
- Which of your habits are changed by this service?

Interview closing

- Thank you for your time. Your response is valuable to me. If you're interested in the results, I can send you the outcomes later.
- Is there anything you would like to add?
- Can you recommend me a peer farmer to talk to about this subject?

E.2 Interview guide for developers **Introduction**

- Hello, I'm Vincent and I'm conducting agricultural research around Khulna.
- Several information services have been developed to support farmers' decisions, but some of them seem to be more successful after introduction than others.
- I'm are interested in your experience with this kind of information, so I'm are approaching service developers for interviewing. Is it okay if I interview you?
- The interview takes about 30 minutes, and the results are saved anonymously and for the purpose of understanding information services only.
- I use a recorder to analyze the questions and listen back if we misunderstood, is that alright?

Introduction questions

- Could you introduce yourself?
- What is your background?
- For who do you work?

Research questions

- Which information services are you involved in?
- What is the age of your target users?
- What is the gender of your target users?
- What is the farming experience of your target users?
- What is the education of your target users?
- Which information do you provide with this service?
- Do you consider the medium of this service to be useful in transferring this information?
- How did you involve users in the design of this service?
- Why do end-users find this service useful?
- How many users do you currently have?
- How many of them are active users?
- Do you monitor which information your active users take up?
- Do you monitor how frequent your active users take up information?
- Which knowledge from this service helps your users to farm?
- Which farming decisions of your users change after getting information from service?
- Which changes can the user observe after using the service?
- How would you rate the cost of the service?
- How would you rate the performance of your service?
- How easy is this service to use?
- Which role does peer recommendation play for using this service?
- Which farmers' habits are changed by this service?
- What do you think would be the best step to improve information uptake of this service?
- Do users of this service provide feedback to the service? (if yes, which data and how frequent)

Interview closing

- Thank you for your time.
- Would you like to add something?
- Can you recommend me another developer to talk to about this subject?
- If you're interested in the results we can send you the outcomes.

E.3 Interview guide for non-users

Introduction

- Hello, I'm Vincent and I'm conducting agricultural research around Khulna.
- Several information services have been developed to support farmers' decisions, but some of them seem to be more successful after introduction than others.
- I'm are interested in your experience with this kind of information, so I'm are approaching farmers for interviewing. Is it okay if I interview you?
- The interview takes about 20-25 minutes, and the results are saved anonymously and for the purpose of understanding information services only.
- We use a recorder to analyze the questions and listen back if we misunderstood, is that alright?

Introduction questions

- Could you introduce yourself?
- What is your age?
- For how long have you been a farmer?
- How many years have you been in school?
- How big is your agricultural land?
- Which crop(s) are you growing now?
- At this point I would like to show you an information service. This holds information that may be of help to you and your farming practices.
- I will first show you the service and you can have a look at it, and later I will ask you some questions about it. I will not explain to you what it exactly does, but I will let you discover it yourself.
- Let me know when you finished analysing this service.

Show one of the following: BMD weather app/dkrisi mobile app/e-Krishok/Agromet bulletin/Krishi Samachar&Chashabad

- Please note that for the questions I'm about to ask, there are no right or wrong answers. All the responses you provide is valuable information for me.

Research questions

- Which type of information did you just obtain?
- Through which medium did you get that information?
- Why do you find this type of information useful?
- Which of your farming decisions do you expect to change after getting such information?
- Which changes do you expect to occur after taking these decisions?
- What do you think would be the best step to improve this service?
- Do you think you would provide feedback to this service?
- How would you rate the costs of this service?

Repeat for next service

Interview closing

- Thank you for your time. All your responses are valuable to me.
- If you are interested I can show you another application and we can repeat the process.
- If not, can you recommend me a peer farmer to talk to?